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(54) Coated hard-alloy blade member.

(57) A coated hard alloy blade member is disclosed which includes a substrate formed of a hard alloy of a WC-based cemented carbide or a TiCN-based cermet, and a hard coating deposited on the substrate. The hard coating includes an inner layer of TiCN having unilaterally grown crystals of an elongated shape and an outer layer of Al_2O_3 having a crystal form κ or $\kappa + \alpha$ wherein $\kappa > \alpha$. The resulting blade member is highly resistant to wear and fracturing, and possesses cutting ability of a higher level.

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BACKGROUND OF THE INVENTION

Technical Field of the Invention

The present invention relates to coated hard alloy blade members or cutting tools having exceptional steel and cast iron cutting ability for both continuous and interrupted cutting.

Background Art

Until now, the use of a coated cemented carbide cutting tool made by using either chemical vapor deposition or physical vapor deposition to apply a coating layer of an average thickness of 0.5-20 μm comprised of either multiple layers or a single layer of one or more of titanium carbide, titanium nitride, titanium carbonitride, titanium oxycarbide titanium oxycarbonitride, and aluminum oxide (hereafter indicated by TiC, TiN, TiCN, TiCO, TiCNO, and Al_2O_3) onto a WC-based cemented carbide substrate for cutting steel or cast iron has been widely recognized.

The most important technological advance that led to the wide usage of the above-mentioned coated cemented carbide cutting tool was, as described in Japanese Patent Application No. 52-46347 and Japanese Patent Application No. 51-27171, the development of an exceptionally tough substrate wherein the surface layer of a WC-based cemented carbide substrate included a lot of Co, a binder metal, in comparison with the interior, whereby the fracture resistance of the coated cemented carbide cutting tool rapidly improved.

In addition, as disclosed in Japanese Patent Application No. 52-156303 and Japanese Patent Application No. 54-83745, the confirmation that, by sintering the WC-based cemented carbide containing nitrogen in a denitrifying atmosphere such as a vacuum, the surface layer of the WC-based cemented carbide substrate can be made from WC-Co which does not include a hard dispersed phase having a B-1 type crystal structure, whereby it is possible to cheaply produce WC-based cemented carbide having more Co in its surface layer than in the interior, was also important.

Concerning the advancement of the coating layer, coated cemented carbides having coating layers wherein the X-ray diffraction peaks of the Ti compounds such as TiC, TiN, and TiCN have a strong (200) orientation and the Al_2O_3 has an α-type crystal structure such as described in Japanese Patent Application No. 61-231416 and coated cemented carbides having coating layers wherein the X-ray diffraction peaks of the Ti compounds such as TiC, TiN, and TiCN have a strong (220) orientation and the Al_2O_3 has a κ-type crystal structure such as described in Japanese Patent Application No. 62-29263 have little variation in the tool life.

Furthermore, Japanese Patent Application No. 2-156663 shows that a coated cemented carbide having a coating layer wherein the TiC has a strong (111) orientation and the Al_2O_3 is of the κ-type has the features that there is less spalling of the coating layer and has a long life.

However, since the Ti compounds such as TiC of Japanese Patent Application No. 61-231416, Japanese Patent Application No. 62-29263, and Japanese Patent Application No. 2-156663 are coated by the normal CVD method, the crystal structure is in a granular form identical to the coating layers of the past, and the cutting ability was not always satisfactory.

Additionally, Japanese Patent Application No. 50-16171 discloses that coating is possible with the use of organic gas for a portion of the reaction gas, at a relatively low temperature. In this patent, the crystal structure of the coating layer is not described, and furthermore, the crystal structure may have a granular form, or the crystals may grow in one direction (elongated crystals) depending on the coating conditions. Moreover, in the references given in this patent, the coating layer is made up of only TiCN, and Al_2O_3 is not disclosed. Additionally, this TiCN had a low bonding strength with the substrate.

SUMMARY OF THE INVENTION

In recent years cutting technology has shown remarkable progress towards unmanned, high speed processes. Therefore, tools which are highly resistant to wear and fracturing are required. Consequently, the present inventors conducted research to develop a coated cemented carbide cutting tool having cutting ability of a higher level.

It was discovered that by coating the surface of a WC-based cemented carbide substrate and a TiCN-based cermet substrate with TiCN having crystals growing in one direction (elongated crystals) as an inner layer, and coating with Al_2O_3 having a crystal structure κ or $\kappa + \alpha$wherein $\kappa > \alpha$ as an outer layer, remarkable steel and cast iron cutting ability was shown for both continuous cutting and interrupted cutting.

Thus, the coated hard alloy blade member in accordance with the present invention comprises a substrate formed of a hard alloy selected from the group consisting of a WC-based cemented carbide and a TiCN-based cermet, and a hard coating deposited on said substrate, the hard coating including an inner layer of TiCN having unilaterally grown crystals of an elongated shape and an outer layer of Al_2O_3 having a crystal form κ or $\kappa + \alpha$ wherein $\kappa > \alpha$.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a photograph of a coated cemented carbide blade member in accordance with the present invention as taken by a scanning electron microscope.

DETAILED DESCRIPTION OF THE INVENTION

The coated hard alloy blade member or cutting tool in accordance with the present invention will now be described in detail.

As mentioned before, the coated hard alloy blade member in accordance with the present invention comprises a substrate formed of a hard alloy selected from the group consisting of a WC-based cemented carbide and a TiCN-based cermet, and a hard coating deposited on said substrate, the hard coating including an inner layer of TiCN having unilaterally grown crystals of an elongated shape and an outer layer of Al_2O_3 having a crystal form κ or $\kappa + \alpha$ wherein $\kappa > \alpha$.

In order to practicalize the present invention, it is first necessary to coat the substrate with elongated crystal TiCN having high bonding strength. If the conditions are such that, for example, during the coating of the TiCN, the percentages of the respective volumes are: $TiCl_4$: 1-10%, CH_3CN: 0.1-5%, N_2: 0-35%, H_2: the rest, the reaction temperature is 800-950 °C, the pressure is 30-500 Torr, and furthermore, the CH_3CN gas is decreased to 0.01-0.1% at the beginning of the coating as a first coating reaction for 1-120 minutes, then the CH_3CN gas is increased to 0.1-1% as a second coating reaction, then elongated crystal TiCN having high bonding strength can be obtained. The thickness of the TiCN coating layer should preferably be 1-20 µm. This is because at less than 1 µm the wear resistance worsens, and at more than 20 µm the fracture resistance worsens.

Furthermore, during the coating of the TiCN, if the reaction temperature or the amount of CH_3CN is increased, the (200) plane component of the X-ray diffraction pattern of the TiCN becomes weaker than the (111) and (220) plane components, the bonding strength with the Al_2O_3 in the upper layer which has κ as its main form increases, and the wear resistance goes up.

Next, Al_2O_3 of κ form or $\kappa + \alpha$ form wherein form $\kappa > \alpha$ is coated. For coating Al_2O_3 which has κ as its principal form, the conditions should be such that, for example, the reaction gas is made up of the following volume percentages in the first 1-120 minutes: $AlCl_3$: 1-20%, HCl: 1-20% and/or H_2S: 0.05-5% as needed, and H_2: the rest, and a first reaction be performed, then afterwards, a second reaction is performed in which $AlCl_3$: 1-20%, CO_2: 0.5-30%, HCl: 1-20% and/or H_2S: 0.05-5% as needed, and H_2: the rest, with the conditions of a reaction temperature of 850-1000 °C and pressure of 30-500 Torr.

The thickness of this Al_2O_3 coating layer should preferably be 0.1-10 µm. At less than 0.1 µm the wear resistance worsens, while at over 10 µm the fracturing resistance worsens.

The combined thickness of the first TiCN layer and the second Al_2O_3 layer should preferably be 2-30 µm.

The K ratio of the $\kappa + \alpha$ Al_2O_3 of the present invention uses a peak from Cu-$\kappa\alpha$ X-ray diffraction, and is determined the following equation, wherein if $\kappa > \alpha$ then the κ ratio is over 50%.

$$\kappa \text{ ratio } (\%) = \frac{I_{\kappa 2.79} + I_{\kappa 1.43}}{I_{\kappa 2.79} + I_{\kappa 1.43} + I_{\alpha 2.085} + I_{\alpha 1.601}} \times 100$$

wherein

$I_{\kappa 2.79}$: The height of the X-ray diffraction peak for ASTM No. 4-0878 with a plane index spacing of d = 2.79

$I_{\kappa 1.43}$: The height of the X-ray diffraction peak for ASTM No. 4-0878 with a plane index spacing of d = 1.43

$I_{\alpha 2.085}$: The height of the X-ray diffraction peak for ASTM No. 10-173 with a plane index spacing of d = 2.085 (the (113) plane)

$I_{\alpha 1.601}$: The height of the X-ray diffraction peak for ASTM No. 10-173 with a plane index spacing of d = 1.601 (the (116) plane)

As further modified embodiments of the present invention, the following are included.

(1) As an outermost layer, either one or both of TiN or TiCN may be coated on the outer Al_2O_3 layer. The reason for this coating layer is to discriminate between areas of use, and a thickness of 0.1-2 μm is preferable.

(2) As an innermost layer, either one or more of TiN, TiC, or TiCN (granular form) may be coated underneath the inner TiCN layer. By coating with this innermost layer, the bonding strength of the elongated crystal TiCN improves and the wear resistance improves. The most preferable thickness for this coating is 0.1-5 μm.

(3) Between the inner TiCN layer and the outer Al_2O_3 layer, either one or more of TiN, TiC, or TiCN (granular form) may be coated as a first intermediate layer. This first intermediate layer improves the wear resistance during low speed cutting. However, during high speed cutting, it worsens the wear resistance. The most preferable thickness for this first intermediate layer is 1-7 μm.

(4) Between the inner TiCN layer and the outer Al_2O_3 layer, either one or both of TiCO, TiCNO is coated as a second intermediate layer. This second intermediate layer increases the bonding strength between the elongated crystal TiCN and the κ or $\kappa + \alpha$ form Al_2O_3. The most preferable thickness of this second intermediate layer is 0. 1-2μm.

(5) It is possible to combine the above-mentioned (1)-(4) as appropriate.

(6) The inner layer coated with elongated crystal TiCN may be divided by one or more TiN layers to define a divided TiCN layer. This divided TiCN layer is less susceptible to chipping, and the fracture resistance improves.

(7) With the divided elongated TiCN described above and the κ or $\kappa + \alpha$ form Al_2O_3, it is possible to coat with an outermost layer of one or both of TiN or TiCN as in (1) above, coat with an innermost layer of one or more of TiN, TiC, or TiCN as in (2) above, coat with a first intermediate layer of one or more of TiC, TiN, or TiCN as in (3) above, coat with a second intermediate layer of one or both of TiCO or TiCNO as in (4) above, or to take a combination of them.

(8) The most preferable composition of the WC-based cemented carbide substrate is, by the percentage of weight, as follows:

Co: 4-12% Nb: 0-4% N: 0-1%	Ti: 0-7% Cr: 0-2% W and C: the rest	Ta: 0-7%

Unavoidable impurities such as O, Fe, Ni, and Mo are also included.

(9) For the WC-based cemented carbide of the present invention, for lathe turning of steel, it is preferable that the cemented carbide be such that the amount of Co or Co + Cr in the surface portion (the highest value from the surface to within 100 μm) be 1.5 to 5 times the amount in the interior (1 mm from the surface), and for lathe turning of cast iron, it is preferable that there is no enrichment of the Co or Co + Cr, and that the amount of Co or Co + Cr be small. Furthermore, in the case of steel milling, cemented carbide in which there has been no enrichment of the Co or Co + Cr, and the amount of Co or Co + Cr is large, is preferable.

(10) The most preferable composition of the TiCN-based cermet substrate is, by the percentage of weight, as follows:

Co: 2-14% Nb: 0.1-10% N: 2-8% Cr, V, Zr, Hf: 0-5%	Ni: 2-12% W: 5-30% Ti and C: the rest	Ta: 2-20% Mo: 5-20%

Unavoidable impurities such as O and Fe are included.

(11) In the TiCN-based cermet of the present invention, the substrate surface layer (the largest value within 100 μm of the surface) should be 5% or more harder than the interior (1 mm from the surface) or there should be no difference between the hardnesses of the surface layer and the interior.

The present invention will be explained in more detail by way of the following examples.

EXAMPLE 1

As the raw materials, medium grain WC powder having an average particle size of 3 µm, 5 µm coarse grain WC powder, 1.5 µm (Ti, W)C (by weight ratio, TiC/WC = 30/70) powder 1.2 µm (Ti, W)(C, N) (TiC/TiN/WC = 24/20/56) powder, 1.5 µm Ti(C, N) (TiC/TiN = 50/50) powder, 1.6 µm (Ta, Nb)C (TaC/NbC = 90/10) powder, 1.8 µm TaC powder, 1.1 µm Mo_2C powder, 1.7 µm ZrC powder, 1.8 µm Cr_3C_2 powder, 2.0 µm Ni powder, 2.2 µm NiAl (Al: 31% by weight) powder, and 1.2 µm Co powder were prepared, then these raw material powders were blended in the compositions shown in Table 1 and wet-mixed in a ball mill for 72 hours. After drying, they were press-shaped into green compacts of the form of ISO CNMG 120408 (cemented carbide substrates A-D, cermet substrates F-G) and SEEN 42 AFTN 1 (cemented carbide substrates E and E'), then these green compacts were sintered under the conditions described in Table 1, thus resulting in the production of cemented carbide substrates A-E, E' and cermet substrates F-G.

Experimental values taken at over 1 mm from the surface of the sintered compacts of the cemented carbide substrates A-E, E' and the cermet substrates F-G are as shown in Table 2.

Furthermore, in the case of the above cemented carbide substrate B, after maintenance in an atmosphere of CH_4 gas at 100 torr and a temperature of 1400 °C for 1 hour, a gradually cooling carburizing procedure was run, then, by removing the carbon and Co attached to the substrate surface using acid and barrel polishing, a Co-rich region 40 µm deep was formed in the substrate surface layer wherein, at a position 10 µm from the surface the maximum Co content was 15% by weight.

Additionally, in the case of cemented carbide substrates A and D above, while sintered, a Co-rich region 20 µm deep was formed wherein, at a position 15 µm from the surface, the maximum Co content was 11% and 9% by weight, respectively, and in the remaining cemented carbide substrates C, E and E', no Co-rich region was formed, and they had similar compositions over their entirety.

In the above cermet substrates F and G, in the sintered state, a surface layer harder than the interior existed. The hardnesses at the surface and 1 mm below the surface for the cermet substrates F and G are shown in Table 2.

Next, after honing the surfaces of the cemented carbide substrates A-E, E' and cermet substrates F and G, by forming coating layers under the special coating conditions shown in Tables 3(a) and 3(b) and having the compositions, crystal structures, orientation of TiCN (shown, starting from the left, in the order of the intensity of the corresponding X-ray diffraction peak) and average thicknesses shown in Table 4 by using a chemical vapor deposition apparatus, the coated cemented carbide cutting tools of the present invention 1-12 and 15-26, the coated cermet cutting tools of the present invention 13, 14, 27, and 28, the coated cemented carbide cutting tools of the prior art 1-12 and 15-26, and the coated cermet cutting tools 13, 14, 27, and 28 of the prior art were produced.

Then, for the coated cemented carbide cutting tools of the present invention 1-10 and 15-24, and the coated cemented carbide cutting tools of the prior art 1-10 and 15-24, a mild steel continuous cutting test was performed under the following conditions,

Workpiece: mild steel round bar
Cutting Speed: 270 m/min
Feed: 0.25 mm/rev
Depth of Cut: 2 mm
Cutting Time: 30 min

in which a determination was made whether or not the cutting failed due to tears made in the workpiece because of chipping of the cutting blade or spalling of the coating layer. Then, for those which were able to cut for the set period of time, the amount of flank wear was measured. Furthermore, an interrupted cutting test was performed under the following conditions,

Workpiece: mild steel round bar with groove
Cutting Speed: 250 m/min
Feed: 0.25 mm/rev
Depth of Cut: 1.5 mm
Cutting Time: 40 min

in which a determination was made whether or not the cutting failed due to trouble such as fracturing or chipping of the cutting blade. Then, for those which were able to cut for the set period of time, the amount of flank wear was measured.

For the coated cemented carbide cutting tools of the present invention 11, 12, 25 and 26, and the coated cemented carbide cutting tools of the prior art 11, 12, 25 and 26, a mild steel milling test was performed under the following conditions,

Workpiece: mild steel square block
Cutting Speed: 250 m/min
Feed: 0.35 mm/tooth
Depth of Cut: 2.5 mm
Cutting Time: 40 min

in which a determination was made whether or not the milling failed due to trouble such as chipping of the cutting blade. Then, for those which were able to cut for the set period of time, the amount of flank wear was measured.

For the coated cermet cutting tools of the present invention 13, 14, 27 and 28, and the coated cermet cutting tools of the prior art 13, 14, 27 and 28, a mild steel continuous cutting test was performed under the following conditions,

Workpiece: mild steel round bar
Cutting Speed: 320 m/min
Feed: 0.25 mm/rev
Depth of Cut: 1 mm
Cutting Time: 20 min

in which a determination was made whether or not the cutting failed due to chipping or fracturing of the cutting blade. Then, for those which were able to cut for the set period of time, the amount of flank wear was measured. Furthermore, an interrupted cutting test was performed under the following conditions,

Workpiece: mild steel round bar with groove
Cutting Speed: 300 m/min
Feed: 0.20 mm/rev
Depth of Cut: 1 mm
Cutting Time: 20 min

in which a determination was made whether or not the cutting failed due to trouble such as chipping of the cutting blade. Then, for those which were able to cut for the set period of time, the amount of flank wear was measured.

The results of the above tests are shown in Tables 4-7. As is able to be seen from Tables 4-7, all of the coated cemented carbide cutting tools and coated cermet cutting tools of the present invention demonstrate the properties that it is difficult to fracture or chip the cutting blades and spalling of the coating layers is rare, in addition to exhibiting superior wear and fracture resistance.

EXAMPLE 2

Using the same cemented carbide substrates A-E, E' and cermet substrates F and G as Example 1, under the same coating conditions as shown in Tables 3(a) and 3(b) in Example 1, by forming coating layers of the composition, crystal structures, and average thicknesses shown in Tables 8 and 9, the coated cemented carbide cutting tools of the present invention 29-40, the coated cermet cutting tools of the present invention 41 and 42, the coated cemented carbide cutting tools of the prior art 29-40. and the coated cermet cutting tools 41 and 42 of the prior art were produced.

Then, for the coated cemented carbide cutting tools of the present invention 29-38, and the coated cemented carbide cutting tools of the prior art 29-38, a mild steel continuous cutting test was performed under the following conditions,

Workpiece: mild steel round bar
Cutting Speed: 250 m/min
Feed: 0.27 mm/rev
Depth of Cut: 2 mm
Cutting Time: 30 min

and an appraisal identical to that of Example 1 was made. Furthermore, an interrupted cutting test was performed under the following conditions,

Workpiece: mild steel round bar with groove
Cutting Speed: 230 m/min
Feed: 0.27 mm/rev
Depth of Cut: 1.5 mm
Cutting Time: 40 min

and an appraisal identical to that of Example 1 was made.

For the coated cemented carbide cutting tools of the present invention 39 and 40, and the coated cemented carbide cutting tools of the prior art 39 and 40, a mild steel milling test was performed under the following conditions,

Workpiece: mild steel square block
Cutting Speed: 230 m/min
Feed: 0.37 mm/tooth
Depth of Cut: 2.5 mm
Cutting Time: 40 min

and an appraisal identical to that of Example 1 was made.

For the coated cermet cutting tools of the present invention 41 and 42, and the coated cermet cutting tools of the prior art 41 and 42, a mild steel continuous cutting test was performed under the following conditions,

Workpiece: mild steel round bar
Cutting Speed: 300 m/min
Feed: 0.27 mm/rev
Depth of Cut: 1 mm
Cutting Time: 20 min

and an appraisal identical to that of Example 1 was made. Furthermore, an interrupted cutting test was performed under the following conditions,

Workpiece: mild steel round bar with groove
Cutting Speed: 280 m/min
Feed: 0.22 mm/rev
Depth of Cut: 1 mm
Cutting Time: 20 min

and an appraisal identical to that of Example 1 was made.

The results of the above tests are shown in Tables 8, 9(a) and 9(b). As is able to be seen from Tables 8, 9(a) and 9(b), all of the coated cemented carbide cutting tools and coated cermet cutting tools of the present invention demonstrate the properties that it is difficult to fracture or chip the cutting blades and spalling of the coating layers is rare, in addition to exhibiting superior wear and fracture resistance.

EXAMPLE 3

Using the same cemented carbide substrates A-E, E' and cermet substrates F and G as Example 1, under the same coating conditions as shown in Tables 3(a) and 3(b) in Example 1, by forming coating layers of the composition, crystal structures, and average thickness shown in Tables 10-13, the coated cemented carbide cutting tools of the present invention 43-54 and 57-68, the coated cermet cutting tools of the present invention 55, 56, 69 and 70, the coated cemented carbide cutting tools of the prior art 43-54 and 57-68, and the coated cermet cutting tools 55, 56, 69 and 70 of the prior art were produced. Figure 1 shows a photograph of the surface layer of the coated cemented carbide cutting tool of the present invention as taken by a scanning electron microscope.

Then, for the coated cemented carbide cutting tools of the present invention 43-52 and 57-66, and the coated cemented carbide cutting tools of the prior art 43-52 and 57-66, a mild steel continuous cutting test was performed under the following conditions.

Workpiece: mild steel round bar
Cutting Speed: 280 m/min
Feed: 0.23 mm/rev
Depth of Cut: 2 mm
Cutting Time: 30 min

and an appraisal identical to that of Example 1 was made. Furthermore, an interrupted cutting test was performed under the following conditions,

Workpiece: mild steel round bar with groove
Cutting Speed: 260 m/min
Feed: 0.23 mm/rev
Depth of Cut: 1.5 mm
Cutting Time: 40 min

and an appraisal identical to that of Example 1 was made.

For the coated cemented carbide cutting tools of the present invention 53, 54, 67 and 68, and the coated cemented carbide cutting tools of the prior art 53, 54, 67 and 68, a mild steel milling test was performed under the following conditions,

Workpiece: mild steel square block
Cutting Speed: 260 m/min
Feed: 0.33 mm/tooth
Depth of Cut: 2.5 mm
Cutting Time: 40 min

and an appraisal identical to that of Example 1 was made.

For the coated cermet cutting tools of the present invention 55, 56, 69 and 70, and the coated cermet cutting tools of the prior art 55, 56, 69 and 70, a mild steel continuous cutting test was performed under the following conditions,

Workpiece: mild steel round bar
Cutting Speed: 330 m/min
Feed: 0.23 mm/rev
Depth of Cut: 1 mm
Cutting Time: 20 min

and an appraisal identical to that of Example 1 was made. Furthermore, an interrupted cutting test was performed under the following conditions,

Workpiece: mild steel round bar with groove
Cutting Speed: 310 m/min
Feed: 0.18 mm/rev
Depth of Cut: 1 mm
Cutting Time: 20 min

and an appraisal identical to that of Example 1 was made.

The results of the above tests are shown in Tables 10-13. As is able to be seen from Tables 10-13, all of the coated cemented carbide cutting tools and coated cermet cutting tools of the present invention demonstrate the properties that it is difficult to fracture or chip the cutting blades and spalling of the coating layers is rare, in addition to exhibiting superior wear and fracture resistance.

EXAMPLE 4

Using the same cemented carbide substrates A-E, E' and cermet substrates F and G as Example 1, under the same coating conditions as shown in Tables 3(a) and 3(b) in Example 1, by forming coating layers of the composition, crystal structures, and average thicknesses shown in Tables 14-17, the coated cemented carbide cutting tools of the present invention 71-82 and 85-96, the coated cermet cutting tools of the present invention 83, 84, 97 and 98, the coated cemented carbide cutting tools of the prior art 71-82 and 85-96, and the coated cermet cutting tools 83, 84, 97 and 98 of the prior art were produced.

Then, for the coated cemented carbide cutting tools of the present invention 71-80 and 85-94, and the coated cemented carbide cutting tools of the prior art 71-80 and 85-94, a mild steel continuous cutting test was performed under the following conditions,

Workpiece: mild steel round bar
Cutting Speed: 260 m/min
Feed: 0.26 mm/rev
Depth of Cut: 2 mm
Cutting Time: 30 min

and an appraisal identical to that of Example 1 was made. Furthermore, an interrupted cutting test was performed under the following conditions,

Workpiece: mild steel round bar with groove
Cutting Speed: 240 m/min
Feed: 0.26 mm/rev
Depth of Cut: 1.5 mm
Cutting Time: 40 min

and an appraisal identical to that of Example 1 was made.

For the coated cemented carbide cutting tools of the present invention 81, 82, 95 and 96, and the coated cemented carbide cutting tools of the prior art 81, 82, 95 and 96, a mild steel milling test was performed under the following conditions,

Workpiece: mild steel square block

Cutting Speed: 240 m/min
Feed: 0.36 mm/tooth
Depth of Cut: 2.5 mm
Cutting Time: 40 min

and an appraisal identical to that of Example 1 was made.

For the coated cermet cutting tools of the present invention 83, 84, 97 and 98, and the coated cermet cutting tools of the prior art 83, 84, 97 and 98, a mild steel continuous cutting test was performed under the following conditions,

Workpiece: mild steel round bar
Cutting Speed: 310 m/min
Feed: 0.26 mm/rev
Depth of Cut: 1 mm
Cutting Time: 20 min

and an appraisal identical to that of Example 1 was made. Furthermore, an interrupted cutting test was performed under the following conditions,

Workpiece: mild steel round bar with groove
Cutting Speed: 290 m/min
Feed: 0.21 mm/rev
Depth of Cut: 1 mm
Cutting Time: 20 min

and an appraisal identical to that of Example 1 was made.

The results of the above tests are shown in Tables 14-17. As is able to be seen from Tables 14-17, all of the coated cemented carbide cutting tools and coated cermet cutting tools of the present invention demonstrate the properties that it is difficult to fracture or chip the cutting blades and spalling of the coating layers is rare, in addition to exhibiting superior wear and fracture resistance.

EXAMPLE 5

Using the same cemented carbide substrates A-E, E' and cermet substrates F and G as Example 1, under the same coating conditions as shown in Tables 3(a) and 3(b) in Example 1, by forming coating layers of the composition, crystal structures, and average thicknesses shown in Tables 18-21, the coated cemented carbide cutting tools of the present invention 99-112 and 122-126, the coated cermet cutting tools of the present invention 113-121, the coated cemented carbide cutting tools of the prior art 99-112 and 122-126, and the coated cermet cutting tools 113-121 of the prior art were produced.

Then, for the coated cemented carbide cutting tools of the present invention 99-112, and the coated cemented carbide cutting tools of the prior art 99-112, a mild steel high-feed continuous cutting test was performed under the following conditions,

Workpiece: mild steel round bar
Cutting Speed: 210 m/min
Feed: 0.38 mm/rev
Depth of Cut: 2 mm
Cutting Time: 30 min

and an appraisal identical to that of Example 1 was made. Furthermore, a deep cut interrupted cutting test was performed under the following conditions,

Workpiece: mild steel round bar
Cutting Speed: 210 m/min
Feed: 0.23 mm/rev
Depth of Cut: 4 mm
Cutting Time: 40 min

and an appraisal identical to that of Example 1 was made.

For the coated cemented carbide cutting tools of the present invention 122-126, and the coated cemented carbide cutting tools of the prior art 122-126, a mild steel milling test was performed under the following conditions,

Workpiece: mild steel square block
Cutting Speed: 260 m/min
Feed: 0.33 mm/tooth
Depth of Cut: 3 mm
Cutting Time: 40 min

and an appraisal identical to that of Example 1 was made.

For the coated cermet cutting tools of the present invention 113-121, and the coated cermet cutting tools of the prior art 113-121, a mild steel continuous cutting test was performed under the following conditions,

Workpiece: mild steel round bar
Cutting Speed: 340 m/min
Feed: 0.22 mm/rev
Depth of Cut: 1 mm
Cutting Time: 20 min

and an appraisal identical to that of Example 1 was made. Furthermore, an interrupted cutting test was performed under the following conditions,

Workpiece: mild steel round bar with groove
Cutting Speed: 320 m/min
Feed: 0.17 mm/rev
Depth of Cut: 1 mm
Cutting Time: 20 min

and an appraisal identical to that of Example 1 was made.

The results of the above tests are shown in Tables 18-21. As is able to be seen from Tables 18-21, all of the coated cemented carbide cutting tools and coated cermet cutting tools of the present invention demonstrate the properties that it is difficult to fracture or chip the cutting blades and spalling of the coating layers is rare, in addition to exhibiting superior wear and fracture resistance.

TABLE 1

Type		Blend Composition (% by weight)						Sintering Conditions		
		Co	(Ti, W)C	(Ti, W)CN	(Ta, Nb)C	Cr_3C_2	WC	Pressure	Temperature (°C)	Holding Time(hours)
Cemented Carbide Substrate	A	6	-	6	4	-	Balance (medium grain)	Vacuum (0.10 torr)	1380	1
	B	5	5	-	5	-	Balance (medium grain)	Vacuum (0.05 torr)	1450	1
	C	9	8	-	5	-	Balance (medium grain)	Vacuum (0.05 torr)	1380	1.5
	D	5	-	5	3	-	Balance (medium grain)	Vacuum (0.05 torr)	1410	1
	E	10	-	-	2	-	Balance (coarse grain)	Vacuum (0.05 torr)	1380	1
	E'	10	-	-	-	0.7	Balance (coarse grain)	Vacuum (0.05 torr)	1380	1
Cermet Substrate	F	30.2 TiC - 23 TiN - 10 TaC - 13 WC - 10 Mo_2C - 0.5 ZrC - 8 Co - 5 Ni - 0.3 NiAl						Vacuum (0.10 torr)	1500	1.5
	G	57 TiCN - 10 TaC - 1 NbC - 9 WC - 9 Mo_2C - 7 Co - 7 Ni						N_2 Atmosphere (10 torr)	1520	1.5

TABLE 2

		Composition of Sintered Body (% by weight)	Hardness	
			Interior (HRA)	Surface (HRA)
Cemented Carbide Substrate	A	6.1 Co - 2.1 Ti - 3.4 Ta - 0.4 Nb - Rest (W + C)	90.5	-
	B	5.2 Co - 1.2 Ti - 4.2 Ta - 0.4 Nb - Rest (W + C)	91.0	-
	C	9.0 Co - 1.9 Ti - 4.3 Ta - 0.4 Nb - Rest (W + C)	90.3	-
	D	5.2 Co - 1.7 Ti - 2.5 Ta - 0.3 Nb - Rest (W + C)	91.1	-
	E	9.8 Co - 1.7 Ta - 0.2 Nb - Rest (W + C)	89.7	-
	E'	9.8 Co - 0.6 Cr - Rest (W + C)	89.8	-
Cermet Substrate	F	9.4 Ta - 12.2 W - 9.4 Mo - 0.4 Zr - 7.9 Co - 5.1 Ni - 0.1 Al - 3.8 N - Rest (Ti + C)	91.7	92.2
	G	9.5 Ta - 0.9 Nb - 8.5 W - 8.5 Mo - 7.1 Co - 7.0 Ni - 6.8 N - Rest (Ti + C)	91.6	92.6

TABLE 3 (a)

(Coating Conditions)

Composition	X-ray Orientation	Gas Composition (% by volume)	Temperature (°C)	Pressure (Torr)
Innermost Layer Granular TiC		$TiCl_4$:2, CH_4:5, H_2:Rest	1020	50
Innermost Layer Granular TiN		$TiCl_4$:2, N_2:25, H_2:Rest	920	50
Innermost Layer Granular TiCN		$TiCl_4$:2, CH_4:4, N_2:20, H_2:Rest	1020	50
Inner Layer Elongated TiCN	(111)(220)(200)	First Reaction - $TiCl_4$:2, CH_3CN:0.05, N_2:20, H_2:Rest Second Reaction - $TiCl_4$:2, CH_3CN:0.6, N_2:20, H_2:Rest	860	50
Inner Layer Elongated TiCN	(220)(111)(200)	First Reaction - $TiCl_4$:2, CH_3CN:0.05, N_2:20, H_2:Rest Second Reaction - $TiCl_4$:2, CH_3CN:0.6, N_2:20, H_2:Rest	900	50
Inner Layer Elongated TiCN	(111)(200)(220)	First Reaction - $TiCl_4$:2, CH_3CN:0.05, N_2:20, H_2:Rest Second Reaction - $TiCl_4$:2, CH_3CN:0.3, N_2:20, H_2:Rest	860	50
Inner Layer Elongated TiCN	(220)(200)(111)	First Reaction - $TiCl_4$:4, CH_3CN:0.05, N_2:20, H_2:Rest Second Reaction - $TiCl_4$:4, CH_3CN:0.3, N_2:20, H_2:Rest	900	50
Inner Layer Granular TiCN	(111)(200)(220)	$TiCl_4$:4, CH_4:6, N_2:2, H_2:Rest	1050	500
Inner Layer Granular TiCN	(220)(200)(111)	$TiCl_4$:4, CH_4:4, N_2:2, H_2:Rest	1050	500
Inner Layer Granular TiCN	(200)(220)(111)	$TiCl_4$:4, CH_4:2, N_2:2, H_2:Rest	1000	100
Divided Layer Granular TiN		$TiCl_4$:2, N_2:25, H_2:Rest	900	200
Divided Layer Granular TiN		$TiCl_4$:2, N_2:25, H_2:Rest	860	200
First Intermediate Layer Granular TiC		$TiCl_4$:2, CH_4:5, H_2:Rest	1020	50
First Intermediate Layer Granular TiCN		$TiCl_4$:2, CH_4:4, N_2:20, H_2:Rest	1020	50
Second Intermediate Layer Granular TiCO		$TiCl_4$:4, CO:6, H_2:Rest	980	50
Second Intermediate Layer Granular TiCNO		$TiCl_4$:4, CH_4:2, N2:1.5, CO_2:0.5, H_2:Rest	1000	50

TABLE 3 (b)

Composition	X-ray Orientation	Gas Composition (% capacity)	Temperature (°C)	Pressure (Torr)
Outer Layer Al_2O_3	100%κ	First Reaction - $AlCl_3$:3%, H_2:Rest Second Reaction - $AlCl_3$:3%, CO_2:5%, H_2S:0.3, H_2:Rest	970	50
Outer Layer Al_2O_3	94%κ	First Reaction - $AlCl_3$:3%, H_2:Rest Second Reaction - $AlCl_3$:3%, CO_2:5%, H_2:Rest	970	50
Outer Layer Al_2O_3	85%κ	First Reaction - $AlCl_3$:3%, H_2:Rest Second Reaction - $AlCl_3$:3%, CO_2:6%, H_2S:0.2, H_2:Rest	980	50
Outer Layer Al_2O_3	73%κ	First Reaction - $AlCl_3$:3%, H_2:Rest Second Reaction - $AlCl_3$:3%, CO_2:6%, H_2:Rest	980	50
Outer Layer Al_2O_3	62%κ	First Reaction - $AlCl_3$:3%, H_2:Rest Second Reaction - $AlCl_3$:3%, CO_2:7%, H_2S:0.2, H_2:Rest	990	50
Outer Layer Al_2O_3	55%κ	First Reaction - $AlCl_3$:3%, H_2:Rest Second Reaction - $AlCl_3$:3%, CO_2:8%, H_2:Rest	1000	50
Outer Layer Al_2O_3	40%κ	First Reaction - $AlCl_3$:3%, H_2S:0.05, H_2:Rest Second Reaction - $AlCl_3$:3%, CO_2:9%, H_2S:0.1, H_2:Rest	1010	50
Outer Layer Al_2O_3	100%α	$AlCl_3$:3%, CO_2:10%, H_2:Rest	1020	100
Outermost Layer Granular TiN		$TiCl_4$:2, N_2:30, H_2:Rest	1020	200
Outermost Layer Granular TiN		$TiCl_4$:2, CH_4:4, N_2:20, H_2:Rest	1020	200

TABLE 4

Type		Substrate Symbol	Hard Coating Layer							Flank Wear (mm)	
			Inner Layer			Outer Layer		Outermost Layer			
			Composition	Crystal Structure	Orientation	Composition	Crystal Structure	Composition	Crystal Structure	Continuous Cutting	Interrupted Cutting
Coated Cementing Carbide Cutting Tool of the Invention	1	A	TiCN(8.4)	Elongated Growth	(111)(220)(200)	Al_2O_3(2.2)	K:94%	TiN(0.5)	Granular	0.17	0.26
	2	A	TiCN(5.5)	Elongated Growth	(220)(111)(200)	Al_2O_3(6.2)	K:85%			0.19	0.28
	3	A	TiCN(11.4)	Elongated Growth	(111)(220)(200)	Al_2O_3(1.8)	K:100%	TiCN-TiN(0.7)	Granular	0.19	0.31
	4	B	TiCN(8.2)	Elongated Growth	(111)(200)(220)	Al_2O_3(2.1)	K:100%	TiN(0.4)	Granular	0.17	0.31
	5	B	TiCN(5.1)	Elongated Growth	(111)(220)(200)	Al_2O_3(5.2)	K:73%			0.21	0.26
	6	C	TiCN(10.2)	Elongated Growth	(220)(111)(200)	Al_2O_3(1.2)	K:55%	TiN(0.3)	Granular	0.22	0.31
	7	C	TiCN(5.4)	Elongated Growth	(220)(200)(111)	Al_2O_3(0.9)	K:62%	TiN(0.6)	Granular	0.26	0.34
	8	D	TiCN(6.4)	Elongated Growth	(111)(220)(200)	Al_2O_3(5.7)	K:73%	TiN(0.2)	Granular	0.16	0.26
	9	D	TiCN(3.7)	Elongated Growth	(220)(111)(200)	Al_2O_3(8.2)	K:62%			0.17	0.30
	10	D	TiCN(7.9)	Elongated Growth	(111)(220)(200)	Al_2O_3(2.5)	K:100%			0.18	0.26
	11	E	TiCN(4.2)	Elongated Growth	(220)(111)(200)	Al_2O_3(0.5)	K:100%			0.17	(Milling)
	12	E'	TiCN(4.0)	Elongated Growth	(111)(220)(200)	Al_2O_3(0.4)	K:94%	TiN(0.3)	Granular	0.19	(Milling)
	13	F	TiCN(4.6)	Elongated Growth	(220)(111)(200)	Al_2O_3(0.4)	K:100%	TiN(0.4)	Granular	0.16	0.29
	14	G	TiCN(3.2)	Elongated Growth	(111)(220)(200)	Al_2O_3(0.8)	K:94%	TiN(0.2)	Granular	0.16	0.27

TABLE 5

Type	No.	Substrate Symbol	Hard Coating Layer							Flank Wear (mm)	
			Inner Layer			Outer Layer		Outermost Layer			
			Composition	Crystal Structure	Orientation	Composition	Crystal Structure	Composition	Crystal Structure	Continuous Cutting	Interrupted Cutting
Coated Cemented Carbide Cutting Tools of Prior Art	1	A	TiCN(8.5)	Granular	(111)(200)(220)	Al_2O_3(2.0)	α:100%	TiN(0.5)	Granular	0.47 (Chipping)	0.60 (Chipping)
	2	A	TiCN(5.4)	Granular	(220)(200)(111)	Al_2O_3(6.0)	α:100%			0.52 (Chipping)	0.56 (Chipping)
	3	A	TiCN(11.3)	Granular	(111)(200)(220)	Al_2O_3(1.9)	K:40%	TiCN-TiN(0.8)	Granular	0.52 (Chipping)	0.65 (Chipping)
	4	B	TiCN(8.1)	Granular	(200)(220)(111)	Al_2O_3(2.2)	α:100%	TiN(0.3)	Granular	Failure after 12.8 min. due to Layer Separation	Failure after 7.5 min. due to Layer Separation
	5	B	TiCN(4.9)	Granular	(111)(200)(220)	Al_2O_3(5.2)	α:100%			Failure after 10.7 min. due to Layer Separation	Failure after 5.3 min. due to Layer Separation
	6	C	TiCN(10.3)	Granular	(220)(200)(111)	Al_2O_3(1.1)	α:100%	TiN(0.4)	Granular	Failure after 5.6 min. due to Layer Separation	Failure after 0.8 min. due to Fracturing
	7	C	TiCN(5.5)	Granular	(200)(220)(111)	Al_2O_3(1.1)	K:40%	TiN(0.5)	Granular	Failure after 10.4 min. due to Layer Separation	Failure after 3.2 min. due to Fracturing
	8	D	TiCN(6.5)	Granular	(111)(200)(220)	Al_2O_3(5.6)	α:100%	TiN(0.3)	Granular	Failure after 17.1 min. due to Chipping	Failure after 7.9 min. due to Chipping
	9	D	TiCN(3.8)	Granular	(220)(200)(111)	Al_2O_3(8.4)	K:40%			Failure after 15.4 min. due to Chipping	Failure after 5.2 min. due to Chipping
	10	D	TiCN(7.7)	Granular	(111)(200)(220)	Al_2O_3(2.4)	α:100%			Failure after 13.6 min. due to Chipping	Failure after 7.0 min. due to Chipping
	11	E	TiCN(4.1)	Granular	(220)(200)(111)	Al_2O_3(0.6)	α:100%			Failure after 20.8 min. due to Chipping (Milling)	
	12	E'	TiCN(3.9)	Granular	(111)(200)(220)	Al_2O_3(0.3)	α:100%	TiN(0.2)	Granular	Failure after 17.7 min. due to Layer Separation (Milling)	
	13	F	TiCN(4.4)	Granular	(220)(200)(111)	Al_2O_3(0.4)	α:100%	TiN(0.4)	Granular	Failure after 1.0 min. due to Chipping	Failure after 0.1 min. due to Fracturing
	14	G	TiCN(3.3)	Granular	(111)(200)(220)	Al_2O_3(0.9)	α:100%	TiN(0.3)	Granular	Failure after 2.8 min. due to Chipping	Failure after 0.2 min. due to Fracturing

TABLE 6

Type	No.	Substrate Symbol	Hard Coating Layer: Innermost Layer: Composition	Innermost Layer: Crystal Structure	Inner Layer: Composition	Inner Layer: Crystal Structure	Inner Layer: Orientation	Outer Layer: Composition	Outer Layer: Crystal Structure	Outermost Layer: Composition	Outermost Layer: Crystal Structure	Flank Wear (mm): Continuous Cutting	Flank Wear (mm): Interrupted Cutting
Coated Cemented Carbide Cutting Tools of the Invention	15	A	TiN (0.9)	Granular	TiCN (8.2)	Elongated Growth	(111)(220)(200)	Al_2O_3 (2.1)	κ:94%	TiN (0.8)	Granular	0.13	0.15
	16	A	TiN (0.5)	Granular	TiCN (5.5)	Elongated Growth	(220)(111)(200)	Al_2O_3 (6.1)	κ:85%			0.15	0.14
	17	A	TiCN (0.8)	Granular	TiCN (11.2)	Elongated Growth	(111)(220)(200)	Al_2O_3 (1.9)	κ:100%	TiCN-TiN (0.8)	Granular	0.18	0.20
	18	B	TiC-TiN (1.5)	Granular	TiCN (8.3)	Elongated Growth	(111)(200)(220)	Al_2O_3 (2.0)	κ:100%	TiN (0.5)	Granular	0.16	0.21
	19	B	TiN (1.5)	Granular	TiCN (4.8)	Elongated Growth	(111)(220)(200)	Al_2O_3 (5.5)	κ:73%			0.17	0.17
	20	C	TiN (0.1)	Granular	TiCN (10.2)	Elongated Growth	(220)(111)(200)	Al_2O_3 (1.2)	κ:55%	TiN (0.3)	Granular	0.17	0.20
	21	C	TiC (0.4)	Granular	TiCN (5.5)	Elongated Growth	(220)(200)(111)	Al_2O_3 (1.0)	κ:62%	TiN (0.5)	Granular	0.20	0.22
	22	D	TiN (0.6)	Granular	TiCN (6.5)	Elongated Growth	(111)(220)(200)	Al_2O_3 (5.3)	κ:73%			0.13	0.16
	23	D	TiN (1.2)	Granular	TiCN (3.9)	Elongated Growth	(220)(111)(200)	Al_2O_3 (8.1)	κ:62%			0.16	0.19
	24	D	TiCN (0.6)	Granular	TiCN (7.8)	Elongated Growth	(111)(220)(200)	Al_2O_3 (2.4)	κ:100%			0.17	0.18
	25	E	TiN (0.3)	Granular	TiCN (4.0)	Elongated Growth	(220)(111)(200)	Al_2O_3 (0.6)	κ:100%			0.13	(Milling)
	26	E	TiN (0.3)	Granular	TiCN (3.5)	Elongated Growth	(111)(220)(200)	Al_2O_3 (0.4)	κ:94%	TiN (0.3)	Granular	0.15	(Milling)
	27	F	TiN (0.7)	Granular	TiCN (4.5)	Elongated Growth	(220)(111)(200)	Al_2O_3 (0.3)	κ:100%	TiN (0.4)	Granular	0.15	0.28
	28	G	TiN-TiCN (0.9)	Granular	TiCN (3.1)	Elongated Growth	(111)(220)(200)	Al_2O_3 (0.7)	κ:94%	TiN (0.2)	Granular	0.14	0.27

TABLE 7 (a)

Type		Substrate Symbol	Hard Coating Layer									Flank Wear (mm)	
			Innermost Layer		Inner Layer			Outer Layer		Outermost Layer			
			Composition	Crystal Structure	Composition	Crystal Structure	Orientation	Composition	Crystal Structure	Composition	Crystal Structure	Continuous Cutting	Interrupted Cutting
Coated Cemented Carbide Cutting Tools of Prior Art	15	A	TiN (1.0)	Granular	TiCN (8.1)	Granular	(111) (200) (220)	Al_2O_3 (2.0)	α:100%	TiN (0.8)	Granular	0.39 (Chipping)	0.53 (Chipping)
	16	A	TiN (0.5)	Granular	TiCN (5.3)	Granular	(220) (200) (111)	Al_2O_3 (6.0)	α:100%			0.43 (Chipping)	0.50 (Chipping)
	17	A	TiCN (0.7)	Granular	TiCN (11.4)	Granular	(111) (200) (220)	Al_2O_3 (2.1)	K:40%	TiCN-TiN (0.7)	Granular	0.51 (Chipping)	0.58 (Chipping)
	18	B	TiC-TiN (1.4)	Granular	TiCN (8.4)	Granular	(200) (220) (111)	Al_2O_3 (1.9)	α:100%	TiN (0.4)	Granular	Failure after 13.2 min. due to Layer Separation	Failure after 8.1 min. due to Layer Separation
	19	B	TiN (1.8)	Granular	TiCN (4.2)	Granular	(111) (200) (220)	Al_2O_3 (4.9)	α:100%			Failure after 14.5 min. due to Layer Separation	Failure after 7.5 min. due to Layer Separation
	20	C	TiN (0.1)	Granular	TiCN (10.0)	Granular	(220) (200) (111)	Al_2O_3 (1.1)	α:100%	TiN (0.3)	Granular	Failure after 8.7 min. due to Layer Separation	Failure after 1.7 min. due to Fracturing
	21	C	TiC (0.5)	Granular	TiCN (5.4)	Granular	(200) (220) (111)	Al_2O_3 (0.9)	K:40%	TiN (0.5)	Granular	Failure after 10.8 min. due to Layer Separation	Failure after 3.7 min. due to Fracturing
	22	D	TiN (0.4)	Granular	TiCN (6.7)	Granular	(111) (200) (220)	Al_2O_3 (5.0)	α:100%			Failure after 20.2 min. due to Chipping	Failure after 10.1 min. due to Chipping
	23	D	TiN (1.1)	Granular	TiCN (3.8)	Granular	(220) (200) (111)	Al_2O_3 (8.2)	K:40%			Failure after 16.1 min. due to Chipping	Failure after 5.8 min. due to Chipping
	24	D	TiCN (0.5)	Granular	TiCN (7.6)	Granular	(111) (200) (220)	Al_2O_3 (2.5)	α:100%			Failure after 14.4 min. due to Chipping	Failure after 7.6 min. due to Chipping

TABLE 7 (b)

Type		Substrate Symbol	Hard Coating Layer									Flank Wear (mm)	
			Innermost Layer		Inner Layer			Outer Layer		Outermost Layer			
			Composition	Crystal Structure	Composition	Crystal Structure	Orientation	Composition	Crystal Structure	Composition	Crystal Structure	Continuous Cutting	Interrupted Cutting
Coated Cemented Carbide Cutting Tools of Prior Art	25	E	TiN (0.3)	Granular	TiCN (3.9)	Granular	(220)(200)(111)	Al_2O_3 (0.6)	α:100%			Failure after 26.7 min. due to Chipping (Milling)	
	26	E'	TiN (0.3)	Granular	TiCN (3.4)	Granular	(111)(200)(220)	Al_2O_3 (0.4)	α:100%	TiN (0.3)	Granular	Failure after 23.3 min. due to Layer Separation (Milling)	
	27	F	TiN (0.6)	Granular	TiCN (4.4)	Granular	(220)(200)(111)	Al_2O_3 (0.4)	α:100%	TiN (0.4)	Granular	Failure after 1.2 min. due to Chipping	Failure after 0.1 min. due to Fracturing
	28	G	TiN-TiCN (1.0)	Granular	TiCN (3.2)	Granular	(111)(200)(220)	Al_2O_3 (0.8)	α:100%	TiN (0.3)	Granular	Failure after 3.0 min. due to Chipping	Failure after 0.2 min. due to Fracturing

TABLE 8

Type	No.	Substrate Symbol	Hard Coating Layer: Innermost Layer: Composition	Innermost Layer: Crystal Structure	Inner Layer: Composition	Inner Layer: Crystal Structure	Inner Layer: Orientation	First Intermediate Layer: Composition	First Intermediate Layer: Crystal Structure	Outer Layer: Composition	Outer Layer: Crystal Structure	Outermost Layer: Composition	Outermost Layer: Crystal Structure	Flank Wear (mm): Continuous Cutting	Flank Wear (mm): Interrupted Cutting
Coated Cemented Carbide Cutting Tools of the Invention	29	A	TiN (0.9)	Granular	TiCN (6.5)	Elongated Growth	(111)(220)(200)	TiC (3.0)	Granular	Al_2O_3 (2.5)	K:94%	TiN (0.2)	Granular	0.15	0.19
	30	A	TiN (0.5)	Granular	TiCN (3.0)	Elongated Growth	(220)(111)(200)	TiC (2.4)	Granular	Al_2O_3 (6.0)	K:85%			0.18	0.18
	31	A			TiCN (9.3)	Elongated Growth	(111)(220)(200)	TiC (2.3)	Granular	Al_2O_3 (2.1)	K:100%	TiCN-TiN (0.8)	Granular	0.18	0.29
	32	B	TiC-TiN (1.1)	Granular	TiCN (4.5)	Elongated Growth	(111)(200)(220)	TiC (3.9)	Granular	Al_2O_3 (1.7)	K:100%	TiN (0.2)	Granular	0.15	0.28
	33	B	TiN (1.6)	Granular	TiCN (4.9)	Elongated Growth	(111)(220)(200)	TiC (1.0)	Granular	Al_2O_3 (4.0)	K:73%			0.19	0.20
	34	C	TiN (0.1)	Granular	TiCN (6.8)	Elongated Growth	(220)(111)(200)	TiC (3.2)	Granular	Al_2O_3 (1.2)	K:55%	TiN (0.3)	Granular	0.19	0.24
	35	C	TiC (0.7)	Granular	TiCN (3.3)	Elongated Growth	(220)(200)(111)	TiN (1.9)	Granular	Al_2O_3 (0.9)	K:62%	TiN (0.3)	Granular	0.25	0.25
	36	D	TiN (0.6)	Granular	TiCN (3.6)	Elongated Growth	(111)(220)(200)	TiC (2.8)	Granular	Al_2O_3 (5.2)	K:73%			0.15	0.20
	37	D			TiCN (2.6)	Elongated Growth	(220)(111)(200)	TiCN (1.0)	Granular	Al_2O_3 (8.0)	K:62%			0.16	0.27
	38	D	TiCN (0.4)	Granular	TiCN (5.6)	Elongated Growth	(111)(220)(200)	TiC (2.3)	Granular	Al_2O_3 (2.7)	K:100%			0.16	0.24
	39	E	TiN (0.3)	Granular	TiCN (2.5)	Elongated Growth	(220)(111)(200)	TiC (1.5)	Granular	Al_2O_3 (0.5)	K:100%			0.15	(Milling)
	40	E'			TiCN (2.7)	Elongated Growth	(111)(220)(200)	TiC (1.6)	Granular	Al_2O_3 (0.3)	K:94%	TiN (0.2)	Granular	0.14	(Milling)
	41	F			TiCN (3.5)	Elongated Growth	(220)(111)(200)	TiCN (1.3)	Granular	Al_2O_3 (0.4)	K:100%	TiN (0.2)	Granular	0.16	0.26
	42	G	TiN-TiCN (1.0)	Granular	TiCN (1.7)	Elongated Growth	(111)(220)(200)	TiC (1.0)	Granular	Al_2O_3 (0.6)	K:94%	TiN (0.3)	Granular	0.14	0.24

TABLE 9 (a)

Type		Substrate Symbol	Hard Coating Layer											Flank Wear (mm)	
			Innermost Layer		Inner Layer			First Intermediate Layer		Outer Layer		Outermost Layer			
			Composition	Crystal Structure	Composition	Crystal Structure	Orientation	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Continuous Cutting	Interrupted Cutting
Coated Cemented Carbide Cutting Tools of Prior Art	29	A	TiN (1.0)	Granular	TiCN (9.3)	Granular	(111)(200)(220)	TiC (2.5)	Granular	Al_2O_3 (2.5)	α:100%	TiN (0.2)	Granular	0.43 (Chipping)	0.54 (Chipping)
	30	A	TiN (0.5)	Granular	TiCN (3.1)	Granular	(220)(200)(111)	TiC (2.1)	Granular	Al_2O_3 (5.6)	α:100%			0.50 (Chipping)	0.53 (Chipping)
	31	A			TiCN (9.5)	Granular	(111)(200)(220)	TiC (2.1)	Granular	Al_2O_3 (2.1)	κ:40%	TiCN-TiN (0.6)	Granular	0.50 (Chipping)	0.48 (Chipping)
	32	B	TiC-TiN (1.2)	Granular	TiCN (4.7)	Granular	(200)(220)(111)	TiC (4.0)	Granular	Al_2O_3 (1.8)	α:100%	TiN (0.2)	Granular	Failure after 13.9 min. due to Layer Separation	Failure after 8.8 min. due to Layer Separation
	33	B	TiN (1.7)	Granular	TiCN (4.8)	Granular	(111)(200)(220)	TiC (1.2)	Granular	Al_2O_3 (3.9)	α:100%			Failure after 11.1 min. due to Layer Separation	Failure after 6.2 min. due to Layer Separation
	34	C	TiN (0.1)	Granular	TiCN (5.8)	Granular	(220)(200)(111)	TiC (2.5)	Granular	Al_2O_3 (1.1)	α:100%	TiN (0.3)	Granular	Failure after 6.8 min. due to Layer Separation	Failure after 1.4 min. due to Fracturing
	35	C	TiC (0.6)	Granular	TiCN (3.2)	Granular	(200)(220)(111)	TiN (1.8)	Granular	Al_2O_3 (1.0)	κ:40%	TiN (0.4)	Granular	Failure after 11.6 min. due to Layer Separation	Failure after 4.1 min. due to Fracturing
	36	D	TiN (0.4)	Granular	TiCN (3.5)	Granular	(111)(200)(220)	TiC (2.9)	Granular	Al_2O_3 (4.8)	α:100%			Failure after 18.5 min. due to Chipping	Failure after 9.2 min. due to Chipping
	37	D			TiCN (2.7)	Granular	(220)(200)(111)	TiCN (1.1)	Granular	Al_2O_3 (8.1)	κ:40%			Failure after 16.8 min. due to Chipping	Failure after 6.4 min. due to Chipping
	38	D	TiCN (0.5)	Granular	TiCN (5.7)	Granular	(111)(200)(220)	TiC (2.5)	Granular	Al_2O_3 (2.7)	α:100%			Failure after 14.7 min. due to Chipping	Failure after 8.2 min. due to Chipping

TABLE 9 (b)

Type		Sub-strate Symbol	Hard Coating Layer											Flank Wear (mm)	
			Innermost Layer		Inner Layer			First Intermediate Layer		Outer Layer		Outermost Layer			
			Compo-sition	Crystal Struc-ture	Compo-sition	Crystal Struc-ture	Orientation	Compo-sition	Crystal Struc-ture	Compo-sition	Crystal Struc-ture	Compo-sition	Crystal Struc-ture	Continuous Cutting	Interrupted Cutting
Coated Cemented Carbide Cutting Tools of Prior Art	39	E	TiN (0.3)	Granular	TiCN (2.5)	Granular	(220)(200)(111)	TiC (1.4)	Granular	Al_2O_3 (0.5)	α:100%			Failure after 19.7 min. due to Chipping (Milling)	
	40	E'			TiCN (2.6)	Granular	(111)(200)(220)	TiC (1.5)	Granular	Al_2O_3 (0.4)	α:100%	TiN (0.3)	Granular	Failure after 19.3 min. due to Layer Separation (Milling)	
	41	F			TiCN (3.4)	Granular	(220)(200)(111)	TiCN (1.4)	Granular	Al_2O_3 (0.3)	α:100%	TiN (0.3)	Granular	Failure after 1.4 min. due to Chipping	Failure after 0.1 min. due to Fracturing
	42	G	TiN-TiCN (0.9)	Granular	TiCN (1.9)	Granular	(111)(200)(220)	TiC (1.1)	Granular	Al_2O_3 (0.7)	α:100%	TiN (0.2)	Granular	Failure after 3.2 min. due to Chipping	Failure after 0.3 min. due to Fracturing

TABLE 10

Type		Substrate Symbol	Hard Coating Layer									Flank Wear (mm)	
			Inner Layer			Second Intermediate Layer		Outer Layer		Outermost Layer			
			Composition	Crystal Structure	Orientation	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Continuous Cutting	Interrupted Cutting
Coated Cemented Carbide Cutting Tools of the Invention	43	A	TiCN (8.4)	Elongated Growth	(111) (220) (200)	TiCNO (0.1)	Granular	Al_2O_3 (2.0)	κ:94%	TiN (0.5)	Granular	0.15	0.17
	44	A	TiCN (5.7)	Elongated Growth	(220) (111) (200)	TiCNO (0.1)	Granular	Al_2O_3 (6.0)	κ:85%			0.16	0.17
	45	A	TiCN (11.4)	Elongated Growth	(111) (220) (200)	TiCNO (0.1)	Granular	Al_2O_3 (1.9)	κ:100%	TiCN-TiN (0.6)	Granular	0.15	0.19
	46	B	TiCN (8.2)	Elongated Growth	(111) (200) (220)	TiCNO (0.1)	Granular	Al_2O_3 (2.1)	κ:100%	TiN (0.3)	Granular	0.14	0.20
	47	B	TiCN (5.0)	Elongated Growth	(111) (220) (200)	TiCO (0.2)	Granular	Al_2O_3 (5.3)	κ:73%			0.17	0.19
	48	C	TiCN (10.2)	Elongated Growth	(220) (111) (200)	TiCO (0.1)	Granular	Al_2O_3 (1.2)	κ:55%	TiN (0.3)	Granular	0.18	0.21
	49	C	TiCN (5.4)	Elongated Growth	(220) (200) (111)	TiCNO (0.1)	Granular	Al_2O_3 (0.9)	κ:62%	TiN (0.4)	Granular	0.22	0.23
	50	D	TiCN (6.5)	Elongated Growth	(111) (220) (200)	TiCNO (0.1)	Granular	Al_2O_3 (5.4)	κ:94%	TiN (0.2)	Granular	0.13	0.18
	51	D	TiCN (3.8)	Elongated Growth	(220) (111) (200)	TiCNO (0.1)	Granular	Al_2O_3 (8.2)	κ:62%			0.12	0.21
	52	D	TiCN (7.7)	Elongated Growth	(111) (220) (200)	TiCNO (0.1)	Granular	Al_2O_3 (2.4)	κ:100%			0.14	0.19
	53	E	TiCN (4.1)	Elongated Growth	(220) (111) (200)	TiCNO (0.1)	Granular	Al_2O_3 (0.6)	κ:100%			0.14 (Milling)	
	54	E'	TiCN (4.0)	Elongated Growth	(111) (220) (200)	TiCNO (0.1)	Granular	Al_2O_3 (0.5)	κ:94%	TiN (0.3)	Granular	0.16 (Milling)	
	55	F	TiCN (4.4)	Elongated Growth	(220) (111) (200)	TiCO (0.1)	Granular	Al_2O_3 (0.3)	κ:100%	TiN (0.3)	Granular	0.12	0.18
	56	G	TiCN (3.0)	Elongated Growth	(111) (220) (200)	TiCNO (0.2)	Granular	Al_2O_3 (0.7)	κ:94%	TiN (0.2)	Granular	0.13	0.17

TABLE 11 (a)

Type		Substrate Symbol	Hard Coating Layer: Inner Layer			Second Intermediate Layer		Outer Layer		Outermost Layer		Flank Wear (mm)	
			Composition	Crystal Structure	Orientation	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Continuous Cutting	Interrupted Cutting
Coated Cemented Carbide Cutting Tools of Prior Art	43	A	TiCN (8.2)	Granular	(111)(200)(220)	TiCNO (0.1)	Granular	Al_2O_3 (2.1)	α:100%	TiN (0.4)	Granular	0.42 (Chipping)	0.54 (Chipping)
	44	A	TiCN (5.5)	Granular	(220)(200)(111)	TiCNO (0.1)	Granular	Al_2O_3 (6.1)	α:100%			0.47 (Chipping)	0.51 (Chipping)
	45	A	TiCN (11.5)	Granular	(111)(200)(220)	TiCNO (0.1)	Granular	Al_2O_3 (1.8)	κ:40%	TiCN-TiN (0.7)	Granular	0.43 (Chipping)	0.55 (Chipping)
	46	B	TiCN (8.3)	Granular	(200)(220)(111)	TiCNO (0.1)	Granular	Al_2O_3 (2.0)	α:100%	TiN (0.3)	Granular	Failure after 17.5 min. due to Layer Separation	Failure after 11.1 min. due to Layer Separation
	47	B	TiCN (4.8)	Granular	(111)(200)(220)	TiCO (0.2)	Granular	Al_2O_3 (5.2)	α:100%			Failure after 14.0 min. due to Layer Separation	Failure after 7.8 min. due to Layer Separation
	48	C	TiCN (10.3)	Granular	(220)(200)(111)	TiCO (0.1)	Granular	Al_2O_3 (1.3)	α:100%	TiN (0.2)	Granular	Failure after 8.2 min. due to Layer Separation	Failure after 1.2 min. due to Fracturing
	49	C	TiCN (5.2)	Granular	(200)(220)(111)	TiCNO (0.1)	Granular	Al_2O_3 (0.9)	κ:40%	TiN (0.5)	Granular	Failure after 13.6 min. due to Layer Separation	Failure after 5.3 min. due to Fracturing
	50	D	TiCN (6.6)	Granular	(111)(200)(220)	TiCNO (0.1)	Granular	Al_2O_3 (5.5)	α:100%	TiN (0.3)	Granular	Failure after 20.7 min. due to Chipping	Failure after 11.4 min. due to Chipping
	51	D	TiCN (3.7)	Granular	(220)(200)(111)	TiCNO (0.1)	Granular	Al_2O_3 (8.1)	κ:40%			Failure after 18.9 min. due to Chipping	Failure after 8.5 min. due to Chipping
	52	D	TiCN (7.8)	Granular	(111)(200)(220)	TiCNO (0.1)	Granular	Al_2O_3 (2.3)	α:100%			Failure after 16.3 min. due to Chipping	Failure after 10.1 min. due to Chipping

TABLE 11 (b)

Type		Substrate Symbol	Hard Coating Layer									Flank Wear (mm)	
			Inner Layer			Second Intermediate Layer		Outer Layer		Outermost Layer			
			Composition	Crystal Structure	Orientation	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Continuous Cutting	Interrupted Cutting
Coated Cemented Carbide Cutting Tools of Prior Art	53	E	TiCN (4.2)	Granular	(220) (200) (111)	TiCNO (0.1)	Granular	Al_2O_3 (0.5)	α:100%			Failure after 26.9 min. due to Chipping (Milling)	
	54	E'	TiCN (4.0)	Granular	(111) (200) (220)	TiCNO (0.1)	Granular	Al_2O_3 (0.4)	α:100%	TiN (0.2)	Granular	Failure after 24.2 min. due to Layer Separation (Milling)	
	55	F	TiCN (4.5)	Granular	(220) (200) (111)	TiCO (0.1)	Granular	Al_2O_3 (0.3)	α:100%	TiN (0.4)	Granular	Failure after 2.0 min. due to Chipping	Failure after 0.2 min. due to Fracturing
	56	G	TiCN (3.2)	Granular	(111) (200) (220)	TiCNO (0.2)	Granular	Al_2O_3 (0.8)	α:100%	TiN (0.2)	Granular	Failure after 5.2 min. due to Chipping	Failure after 0.7 min. due to Fracturing

TABLE 12

Type		Sub-strate Symbol	Hard Coating Layer												Flank Wear (mm)	
			Innermost Layer		Inner Layer			Second Intermediate Layer		Outer Layer		Outermost Layer				
			Compo-sition	Crystal Struc-ture	Compo-sition	Crystal Structure	Orientation	Compo-sition	Crystal Struc-ture	Compo-sition	Crystal Struc-ture	Compo-sition	Crystal Structure		Conti-nuous Cutting	Inter-rupted Cutting
Coated Cemented Carbide Cutting Tools of the Invention	57	A	TiN (1.0)	Granular	TiCN (8.5)	Elongated Growth	(111) (220) (200)	TiCNO (0.1)	Granular	Al_2O_3 (2.2)	K:94%	TiN (0.5)	Granular		0.13	0.14
	58	A	TiN (0.5)	Granular	TiCN (5.6)	Elongated Growth	(220) (111) (200)	TiCNO (0.1)	Granular	Al_2O_3 (6.0)	K:85%				0.15	0.13
	59	A	TiCN (0.8)	Granular	TiCN (11.5)	Elongated Growth	(111) (220) (200)	TiCNO (0.1)	Granular	Al_2O_3 (1.8)	K:100%	TiCN-TiN (0.7)	Granular		0.14	0.15
	60	B	TiC-TiN (1.4)	Granular	TiCN (8.2)	Elongated Growth	(111) (200) (220)	TiCNO (0.1)	Granular	Al_2O_3 (2.0)	K:100%	TiN (0.3)	Granular		0.13	0.16
	61	B	TiN (1.6)	Granular	TiCN (4.9)	Elongated Growth	(111) (220) (200)	TiCO (0.2)	Granular	Al_2O_3 (5.1)	K:73%				0.16	0.17
	62	C	TiN (0.1)	Granular	TiCN (10.1)	Elongated Growth	(220) (111) (200)	TiCO (0.1)	Granular	Al_2O_3 (1.1)	K:55%	TiN (0.3)	Granular		0.17	0.19
	63	C	TiC (0.5)	Granular	TiCN (5.3)	Elongated Growth	(220) (200) (111)	TiCNO (0.1)	Granular	Al_2O_3 (0.9)	K:62%	TiN (0.5)	Granular		0.20	0.21
	64	D	TiN (0.6)	Granular	TiCN (6.4)	Elongated Growth	(111) (220) (200)	TiCNO (0.1)	Granular	Al_2O_3 (5.6)	K:94%	TiN (0.2)	Granular		0.12	0.15
	65	D	TiN (1.2)	Granular	TiCN (3.8)	Elongated Growth	(220) (111) (200)	TiCNO (0.1)	Granular	Al_2O_3 (8.3)	K:62%				0.11	0.17
	66	D	TiCN (0.4)	Granular	TiCN (7.8)	Elongated Growth	(111) (220) (200)	TiCNO (0.1)	Granular	Al_2O_3 (2.5)	K:100%				0.13	0.15
	67	E	TiN (0.3)	Granular	TiCN (4.2)	Elongated Growth	(220) (111) (200)	TiCNO (0.1)	Granular	Al_2O_3 (0.6)	K:100%				0.12	(Milling)
	68	E'	TiN (0.3)	Granular	TiCN (4.1)	Elongated Growth	(111) (220) (200)	TiCNO (0.1)	Granular	Al_2O_3 (0.4)	K:94%	TiN (0.3)	Granular		0.14	(Milling)
	69	F	TiN (0.7)	Granular	TiCN (4.6)	Elongated Growth	(220) (111) (200)	TiCO (0.1)	Granular	Al_2O_3 (0.3)	K:100%	TiN (0.5)	Granular		0.11	0.16
	70	G	TiN-TiCN (1.0)	Granular	TiCN (3.1)	Elongated Growth	(111) (220) (200)	TiCNO (0.2)	Granular	Al_2O_3 (0.8)	K:94%	TiN (0.2)	Granular		0.11	0.15

TABLE 13 (a)

Type	No.	Sub-strate Symbol	Hard Coating Layer: Innermost Layer Composition	Innermost Layer Crystal Structure	Inner Layer Composition	Inner Layer Crystal Structure	Inner Layer Orientation	Second Intermediate Layer Composition	Second Intermediate Layer Crystal Structure	Outer Layer Composition	Outer Layer Crystal Structure	Outermost Layer Composition	Outermost Layer Crystal Structure	Flank Wear (mm) Continuous Cutting	Flank Wear (mm) Interrupted Cutting
Coated Cemented Carbide Cutting Tools of Prior Art	57	A	TiN (1.0)	Granular	TiCN (8.4)	Granular	(111)(200)(220)	TiCNO (0.1)	Granular	Al_2O_3 (2.1)	α:100%	TiN (0.5)	Granular	0.38 (Chipping)	0.51 (Chipping)
	58	A	TiN (0.6)	Granular	TiCN (5.3)	Granular	(220)(200)(111)	TiCNO (0.1)	Granular	Al_2O_3 (5.9)	α:100%			0.41 (Chipping)	0.49 (Chipping)
	59	A	TiCN (0.7)	Granular	TiCN (11.3)	Granular	(111)(200)(220)	TiCNO (0.1)	Granular	Al_2O_3 (1.7)	κ:40%	TiCN-TiN (0.6)	Granular	0.40 (Chipping)	0.54 (Chipping)
	60	B	TiC-TiN (1.5)	Granular	TiCN (8.1)	Granular	(200)(220)(111)	TiCNO (0.1)	Granular	Al_2O_3 (2.2)	α:100%	TiN (0.3)	Granular	Failure after 18.8 min. due to Layer Separation	Failure after 12.3 min. due to Layer Separation
	61	B	TiN (1.6)	Granular	TiCN (4.8)	Granular	(111)(200)(220)	TiCO (0.2)	Granular	Al_2O_3 (5.0)	α:100%			Failure after 15.1 min. due to Layer Separation	Failure after 8.6 min. due to Layer Separation
	62	C	TiN (0.1)	Granular	TiCN (10.2)	Granular	(220)(200)(111)	TiCO (0.1)	Granular	Al_2O_3 (5.0)	α:100%	TiN (0.3)	Granular	Failure after 9.0 min. due to Layer Separation	Failure after 1.7 min. due to Fracturing
	63	C	TiC (0.4)	Granular	TiCN (5.4)	Granular	(200)(220)(111)	TiCNO (0.1)	Granular	Al_2O_3 (1.0)	κ:40%	TiN (0.6)	Granular	Failure after 14.6 min. due to Layer Separation	Failure after 5.9 min. due to Fracturing
	64	D	TiN (0.5)	Granular	TiCN (6.6)	Granular	(111)(200)(220)	TiCNO (0.1)	Granular	Al_2O_3 (5.3)	α:100%			Failure after 21.4 min. due to Chipping	Failure after 12.3 min. due to Chipping
	65	D	TiN (1.3)	Granular	TiCN (3.9)	Granular	(220)(200)(111)	TiCNO (0.1)	Granular	Al_2O_3 (8.2)	κ:40%			Failure after 19.5 min. due to Chipping	Failure after 9.3 min. due to Chipping
	66	D	TiCN (0.5)	Granular	TiCN (7.7)	Granular	(111)(200)(220)	TiCNO (0.1)	Granular	Al_2O_3 (2.3)	α:100%			Failure after 17.1 min. due to Chipping	Failure after 10.8 min. due to Chipping

TABLE 13 (b)

Type		Substrate Symbol	Hard Coating Layer											Flank Wear (mm)	
			Innermost Layer		Inner Layer			Second Intermediate Layer		Outer Layer		Outermost Layer			
			Composition	Crystal Structure	Composition	Crystal Structure	Orientation	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Continuous Cutting	Interrupted Cutting
Coated Cemented Carbide Cutting Tools of Prior Art	67	E	TiN (0.3)	Granular	TiCN (4.0)	Granular	(220)(200)(111)	TiCNO (0.1)	Granular	Al_2O_3 (0.6)	α:100%			Failure after 28.0 min. due to Chipping (Milling)	
	68	E'	TiN (0.3)	Granular	TiCN (3.9)	Granular	(111)(200)(220)	TiCNO (0.1)	Granular	Al_2O_3 (0.4)	α:100%	TiN (0.3)	Granular	Failure after 24.8 min. due to Layer Separation (Milling)	
	69	F	TiN (0.7)	Granular	TiCN (4.5)	Granular	(220)(200)(111)	TiCO (0.1)	Granular	Al_2O_3 (0.4)	α:100%	TiN (0.4)	Granular	Failure after 2.5 min. due to Chipping	Failure after 0.2 min. due to Fracturing
	70	G	TiN-TiCN (1.0)	Granular	TiCN (3.3)	Granular	(111)(200)(220)	TiCNO (0.2)	Granular	Al_2O_3 (0.9)	α:100%	TiN (0.2)	Granular	Failure after 5.7 min. due to Chipping	Failure after 0.9 min. due to Fracturing

TABLE 14

Type		Substrate Symbol	Hard Coating Layer											Flank Wear (mm)	
			Inner Layer			First Intermediate Layer		Second Intermediate Layer		Outer Layer		Outermost Layer			
			Composition	Crystal Structure	Orientation	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Continuous Cutting	Interrupted Cutting
Coated Cemented Carbide Cutting Tools of the Invention	71	A	TiCN (6.3)	Elongated Growth	(111) (220) (200)	TiC (3.2)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (2.3)	κ:94%	TiN (0.2)	Granular	0.16	0.20
	72	A	TiCN (3.1)	Elongated Growth	(220) (111) (200)	TiC (2.0)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (6.0)	κ:85%			0.19	0.19
	73	A	TiCN (9.4)	Elongated Growth	(111) (220) (200)	TiC (2.0)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (2.1)	κ:100%	TiCN-TiN (0.7)	Granular	0.16	0.21
	74	B	TiCN (4.6)	Elongated Growth	(111) (200) (220)	TiC (3.8)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (2.0)	κ:100%	TiN (0.3)	Granular	0.15	0.23
	75	B	TiCN (4.8)	Elongated Growth	(111) (220) (200)	TiC (1.4)	Granular	TiCO (0.1)	Granular	Al_2O_3 (3.8)	κ:73%			0.19	0.21
	76	C	TiCN (6.6)	Elongated Growth	(220) (111) (200)	TiC (3.1)	Granular	TiCO (0.2)	Granular	Al_2O_3 (1.0)	κ:55%	TiN (0.3)	Granular	0.20	0.24
	77	C	TiCN (3.3)	Elongated Growth	(220) (200) (111)	TiN (1.9)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (0.8)	κ:62%	TiN (0.5)	Granular	0.25	0.25
	78	D	TiCN (3.5)	Elongated Growth	(111) (220) (200)	TiC (2.9)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (5.2)	κ:73%	TiN (0.5)	Granular	0.15	0.19
	79	D	TiCN (2.4)	Elongated Growth	(220) (111) (200)	TiCN (0.6)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (8.0)	κ:62%			0.14	0.22
	80	D	TiCN (5.5)	Elongated Growth	(111) (220) (200)	TiC (2.6)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (2.7)	κ:100%			0.15	0.21
	81	E	TiCN (2.6)	Elongated Growth	(220) (111) (200)	TiC (1.3)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (0.5)	κ:100%			0.15 (Milling)	
	82	E'	TiCN (2.3)	Elongated Growth	(111) (220) (200)	TiC (1.5)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (0.4)	κ:94%	TiN (0.2)	Granular	0.17 (Milling)	
	83	F	TiCN (3.4)	Elongated Growth	(220) (111) (200)	TiCN (1.2)	Granular	TiCO (0.1)	Granular	Al_2O_3 (0.4)	κ:100%	TiN (0.3)	Granular	0.14	0.20
	84	G	TiCN (1.9)	Elongated Growth	(111) (220) (200)	TiC (1.0)	Granular	TiCNO (0.2)	Granular	Al_2O_3 (0.8)	κ:94%	TiN (0.3)	Granular	0.13	0.19

TABLE 15 (a)

Type		Sub-strate Symbol	Hard Coating Layer											Flank Wear (mm)	
			Inner Layer			First Intermediate Layer		Second Intermediate Layer		Outer Layer		Outermost Layer			
			Compo-sition	Crystal Struc-ture	Orientation	Compo-sition	Crystal Struc-ture	Compo-sition	Crystal Struc-ture	Compo-sition	Crystal Struc-ture	Compo-sition	Crystal Struc-ture	Continuous Cutting	Interrupted Cutting
Coated Cemented Carbide Cutting Tools of Prior Art	71	A	TiCN (6.2)	Granular	(111) (200) (220)	TiC (3.2)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (2.5)	α:100%	TiN (0.3)	Granular	0.43 (Chipping)	0.53 (Chipping)
	72	A	TiCN (3.0)	Granular	(220) (200) (111)	TiC (2.0)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (5.9)	α:100%			0.49 (Chipping)	0.52 (Chipping)
	73	A	TiCN (9.3)	Granular	(111) (200) (220)	TiC (2.1)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (2.2)	κ:40%	TiCN-TiN (0.6)	Granular	0.37 (Chipping)	0.40 (Chipping)
	74	B	TiCN (4.7)	Granular	(200) (220) (111)	TiC (3.7)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (1.9)	α:100%	TiN (0.2)	Granular	Failure after 14.7 min. due to Layer Separation	Failure after 9.5 min. due to Layer Separation
	75	B	TiCN (4.8)	Granular	(111) (200) (220)	TiC (1.2)	Granular	TiCO (0.1)	Granular	Al_2O_3 (3.7)	α:100%			Failure after 12.1 min. due to Layer Separation	Failure after 6.3 min. due to Layer Separation
	76	C	TiCN (6.7)	Granular	(220) (200) (111)	TiC (2.9)	Granular	TiCO (0.2)	Granular	Al_2O_3 (1.2)	α:100%	TiN (0.4)	Granular	Failure after 6.8 min. due to Layer Separation	Failure after 1.2 min. due to Fracturing
	77	C	TiCN (3.2)	Granular	(200) (220) (111)	TiN (1.8)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (0.8)	κ:40%	TiN (0.4)	Granular	Failure after 11.9 min. due to Layer Separation	Failure after 4.4 min. due to Fracturing
	78	D	TiCN (3.4)	Granular	(111) (200) (220)	TiC (2.8)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (5.1)	α:100%	TiN (0.3)	Granular	Failure after 18.6 min. due to Chipping	Failure after 9.5 min. due to Chipping
	79	D	TiCN (2.4)	Granular	(220) (200) (111)	TiCN (1.3)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (8.1)	κ:40%			Failure after 17.0 min. due to Chipping	Failure after 6.8 min. due to Chipping
	80	D	TiCN (5.3)	Granular	(111) (200) (220)	TiC (2.5)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (2.6)	α:100%			Failure after 15.9 min. due to Chipping	Failure after 8.4 min. due to Chipping

TABLE 15 (b)

Type		Substrate Symbol	Hard Coating Layer											Flank Wear (mm)	
			Inner Layer			First Intermediate Layer		Second Intermediate Layer		Outer Layer		Outermost Layer			
			Composition	Crystal Structure	Orientation	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Continuous Cutting	Interrupted Cutting
Coated Cemented Carbide Cutting Tools of Prior Art	81	E	TiCN (2.4)	Granular	(220) (200) (111)	TiC (1.5)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (0.4)	α:100%			Failure after 23.2 min. due to Chipping (Milling)	
	82	E'	TiCN (2.5)	Granular	(111) (200) (220)	TiC (1.4)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (0.4)	α:100%	TiN (0.2)	Granular	Failure after 20.1 min. due to Layer Separation (Milling)	
	83	F	TiCN (3.3)	Granular	(220) (200) (111)	TiCN (1.3)	Granular	TiCO (0.1)	Granular	Al_2O_3 (0.3)	α:100%	TiN (0.2)	Granular	Failure after 1.6 min. due to Chipping	Failure after 0.1 min. due to Fracturing
	84	G	TiCN (1.8)	Granular	(111) (200) (220)	TiC (1.0)	Granular	TiCNO (0.2)	Granular	Al_2O_3 (0.7)	α:100%	TiN (0.3)	Granular	Failure after 3.5 min. due to Chipping	Failure after 0.3 min. due to Fracturing

TABLE 16

Type		Substrate Symbol	Hard Coating Layer												Flank Wear (mm)	
			Innermost Layer		Inner Layer			First Intermediate Layer		Second Intermediate Layer		Outer Layer		Outermost Layer		
			Composition	Crystal Structure	Composition	Crystal Structure	Orientation	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Continuous Cutting	Interrupted Cutting
Coated Cemented Carbide Cutting Tools of the Invention	85	A	TiN (0.8)	Granular	TiCN (6.4)	Elongated Growth	(111)(220)(200)	TiC (3.0)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (2.5)	K:94%	TiN (0.2)	Granular	0.15	0.19
	86	A	TiN (0.4)	Granular	TiCN (3.0)	Elongated Growth	(220)(111)(200)	TiC (2.3)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (5.9)	K:85%			0.17	0.18
	87	A	TiCN (0.7)	Granular	TiCN (9.2)	Elongated Growth	(111)(220)(200)	TiC (2.1)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (2.0)	K:100%	TiCN-TiN (0.6)	Granular	0.15	0.20
	88	B	TiC-TiN (1.2)	Granular	TiCN (4.7)	Elongated Growth	(111)(200)(220)	TiC (3.8)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (1.9)	K:100%	TiN (0.2)	Granular	0.14	0.22
	89	B	TiN (1.5)	Granular	TiCN (4.8)	Elongated Growth	(111)(220)(200)	TiC (1.2)	Granular	TiCO (0.1)	Granular	Al_2O_3 (3.9)	K:73%			0.18	0.19
	90	C	TiN (0.1)	Granular	TiCN (6.7)	Elongated Growth	(220)(111)(200)	TiC (3.0)	Granular	TiCO (0.2)	Granular	Al_2O_3 (1.1)	K:55%	TiN (0.3)	Granular	0.18	0.23
	91	C	TiC (0.7)	Granular	TiCN (3.2)	Elongated Growth	(220)(200)(111)	TiN (1.7)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (0.8)	K:62%	TiN (0.5)	Granular	0.23	0.24
	92	D	TiN (0.6)	Granular	TiCN (3.6)	Elongated Growth	(111)(220)(200)	TiC (2.8)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (5.1)	K:73%			0.13	0.19
	93	D	TiN (1.0)	Granular	TiCN (2.3)	Elongated Growth	(220)(111)(200)	TiCN (1.2)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (8.1)	K:62%			0.13	0.21
	94	D	TiCN (0.4)	Granular	TiCN (5.4)	Elongated Growth	(111)(220)(200)	TiC (2.5)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (2.8)	K:100%			0.14	0.20
	95	E	TiN (0.3)	Granular	TiCN (2.6)	Elongated Growth	(220)(111)(200)	TiC (1.4)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (0.5)	K:100%			0.14	(Milling)
	96	E'	TiN (0.3)	Granular	TiCN (2.5)	Elongated Growth	(111)(220)(200)	TiC (1.5)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (0.3)	K:94%	TiN (0.2)	Granular	0.16	(Milling)
	97	F	TiN (0.5)	Granular	TiCN (3.2)	Elongated Growth	(220)(111)(200)	TiCN (1.4)	Granular	TiCO (0.1)	Granular	Al_2O_3 (0.3)	K:100%	TiN (0.3)	Granular	0.13	0.19
	98	G	TiN-TiCN (1.1)	Granular	TiCN (1.9)	Elongated Growth	(111)(220)(200)	TiC (1.0)	Granular	TiCNO (0.2)	Granular	Al_2O_3 (0.7)	K:94%	TiN (0.2)	Granular	0.13	0.18

TABLE 17

Type		Substrate Symbol	Hard Coating Layer													Flank Wear (mm)	
			Innermost Layer		Inner Layer			First Intermediate Layer		Second Intermediate Layer		Outer Layer		Outermost Layer			
			Composition	Crystal Structure	Composition	Crystal Structure	Orientation	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Continuous Cutting	Interrupted Cutting
Coated Cemented Carbide Cutting Tools of Prior Art	85	A	TiN (0.9)	Granular	TiCN (6.0)	Granular	(111)(200)(220)	TiC (3.3)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (2.4)	α:100%	TiN (0.2)	Granular	0.41 (Chipping)	0.52 (Chipping)
	86	A	TiN (0.4)	Granular	TiCN (3.2)	Granular	(220)(200)(111)	TiC (2.0)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (5.8)	α:100%			0.48 (Chipping)	0.50 (Chipping)
	87	A	TiCN (0.5)	Granular	TiCN (9.3)	Granular	(111)(200)(220)	TiC (2.2)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (2.2)	K:40%	TiCN-TiN (0.7)	Granular	0.35 (Chipping)	0.39 (Chipping)
	88	B	TiC-TiN (1.3)	Granular	TiCN (4.6)	Granular	(200)(220)(111)	TiC (3.9)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (1.8)	α:100%	TiN (0.2)	Granular	Failure after 15.1 min. due to Layer Separation	Failure after 9.8 min due to Layer Separation
	89	B	TiN (1.6)	Granular	TiCN (4.7)	Granular	(111)(200)(220)	TiC (1.3)	Granular	TiCO (0.1)	Granular	Al_2O_3 (3.8)	α:100%			Failure after 12.6 min. due to Layer Separation	Failure after 6.3 min due to Layer Separation
	90	C	TiN (0.1)	Granular	TiCN (6.5)	Granular	(220)(200)(111)	TiC (3.0)	Granular	TiCO (0.2)	Granular	Al_2O_3 (1.1)	α:100%	TiN (0.3)	Granular	Failure after 7.1 min. due to Layer Separation	Failure after 1.5 min due to Fracturing
	91	C	TiC (0.8)	Granular	TiCN (3.1)	Granular	(200)(220)(111)	TiN (1.8)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (0.9)	K:40%	TiN (0.4)	Granular	Failure after 13.5 min. due to Layer Separation	Failure after 4.7 min. due to Fracturing
	92	D	TiN (0.5)	Granular	TiCN (3.4)	Granular	(111)(200)(220)	TiC (2.9)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (5.0)	α:100%			Failure after 19.2 min. due to Chipping	Failure after 9.8 min due to Chipping
	93	D	TiN (0.9)	Granular	TiCN (2.5)	Granular	(220)(200)(111)	TiCN (1.3)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (8.2)	K:40%			Failure after 17.6 min due to Chipping	Failure after 7.2 min due to Chipping
	94	D	TiCN (0.5)	Granular	TiCN (5.5)	Granular	(111)(200)(220)	TiC (2.4)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (2.6)	α:100%			Failure after 16.3 min due to Chipping	Failure after 8.7 min due to Chipping
	95	E	TiN (0.3)	Granular	TiCN (2.5)	Granular	(220)(200)(111)	TiC (1.4)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (0.5)	α:100%			Failure after 33.7 min due to Chipping (Milling)	
	96	E	TiN (0.3)	Granular	TiCN (2.4)	Granular	(111)(200)(220)	TiC (1.5)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (0.3)	α:100%	TiN (0.2)	Granular	Failure after 20.7 min due to Layer Separation (Milling)	
	97	F	TiN (0.4)	Granular	TiCN (3.3)	Granular	(220)(200)(111)	TiCN (1.3)	Granular	TiCO (0.1)	Granular	Al_2O_3 (0.4)	α:100%	TiN (0.3)	Granular	Failure after 1.8 min due to Chipping	Failure after 0.1 min due to Fracturing
	98	G	TiN-TiCN (1.0)	Granular	TiCN (1.8)	Granular	(111)(200)(220)	TiC (1.1)	Granular	TiCNO (0.2)	Granular	Al_2O_3 (0.8)	α:100%	TiN (0.3)	Granular	Failure after 3.9 min due to Chipping	Failure after 0.4 min due to Fracturing

TABLE 18 (a)

Type		Substrate Symbol	Hard Coating Layer															
			Innermost Layer		Inner Layer													
					First Divided Layer		First Dividing Layer		Second Divided Layer		Second Dividing Layer		Third Divided Layer		Third Dividing Layer		Forth Divided Layer	
			Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure
Coated Cemented Carbide Cutting Tools of the Invention	99	A	TiN (1.0)	Granular	TiCN (2.4)	Elongated Growth	TiN (0.3)	Granular	TiCN (2.4)	Elongated Growth	TiN (0.2)	Granular	TiCN (2.4)	Elongated Growth	TiN (0.2)	Granular	TiCN (2.3)	Elongated Growth
	100	A			TiCN (3.0)	Elongated Growth	TiN (0.2)	Granular	TiCN (3.0)	Elongated Growth								
	101	A	TiN (0.5)	Granular	TiCN (3.2)	Elongated Growth	TiN (0.2)	Granular	TiCN (3.1)	Elongated Growth								
	102	A	TiN (0.5)	Granular	TiCN (3.1)	Elongated Growth	TiN (0.2)	Granular	TiCN (3.0)	Elongated Growth								
	103	B			TiCN (2.7)	Elongated Growth	TiN (0.2)	Granular	TiCN (2.7)	Elongated Growth	TiN (0.2)	Granular	TiCN (2.6)	Elongated Growth				
	104	B	TiC-TiN (1.4)	Granular	TiCN (2.2)	Elongated Growth	TiN (0.3)	Granular	TiCN (2.3)	Elongated Growth								
	105	B	TiN (1.6)	Granular	TiCN (3.4)	Elongated Growth	TiN (0.2)	Granular	TiCN (2.6)	Elongated Growth	TiN (0.2)	Granular	TiCN (2.8)	Elongated Growth				
	106	C			TiCN (4.7)	Elongated Growth	TiN (0.2)	Granular	TiCN (4.8)	Elongated Growth								
	107	C	TiC (0.5)	Granular	TiCN (1.1)	Elongated Growth	TiN (0.1)	Granular	TiCN (0.8)	Elongated Growth	TiN (0.2)	Granular	TiCN (1.0)	Elongated Growth				
	108	C	TiN (0.5)	Granular	TiCN (2.5)	Elongated Growth	TiN (0.3)	Granular	TiCN (2.3)	Elongated Growth	TiN (0.2)	Granular	TiCN (2.4)	Elongated Growth				
	109	D	TiN (0.6)	Granular	TiCN (3.2)	Elongated Growth	TiN (0.3)	Granular	TiCN (3.2)	Elongated Growth								
	110	D	TiN (0.8)	Granular	TiCN (1.2)	Elongated Growth	TiN (0.2)	Granular	TiCN (1.0)	Elongated Growth								
	111	D	TiCN (0.6)	Granular	TiCN (2.0)	Elongated Growth	TiN (0.3)	Granular	TiCN (1.8)	Elongated Growth	TiN (0.2)	Granular	TiCN (1.9)	Elongated Growth	TiN (0.2)	Granular	TiCN (1.7)	Elongated Growth
	112	D			TiCN (3.4)	Elongated Growth	TiN (0.2)	Granular	TiCN (3.5)	Elongated Growth								

TABLE 18 (b)

Type		Substrate Symbol	Hard Coating Layer									Flank Wear (mm)	
			Inner Layer	First Intermediate Layer		Second Intermediate Layer		Outer Layer		Outermost Layer			
			Orientation	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	High-feed Cutting	Deep-cut Cutting
Coated Cemented Carbide Cutting Tools of the Invention	99	A	(111)(220)(200)			TiCNO (0.1)	Granular	Al_2O_3 (2.5)	K:94%	TiN (0.2)	Granular	0.15	0.15
	100	A	(220)(111)(200)	TiC (3.0)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (2.7)	K:100%	TiN (0.2)	Granular	0.16	0.20
	101	A	(111)(220)(200)	TiC (1.9)	Granular			Al_2O_3 (2.0)	K:100%	TiCN-TiN (0.6)	Granular	0.17	0.18
	102	A	(111)(200)(220)	TiC (3.0)	Granular			Al_2O_3 (2.7)	K:73%	TiN (0.2)	Granular	0.21	0.19
	103	B	(111)(220)(200)			TiCO (0.1)	Granular	Al_2O_3 (3.4)	K:100%			0.16	0.22
	104	B	(111)(200)(220)	TiC (3.8)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (1.9)	K:73%	TiN (0.2)	Granular	0.15	0.17
	105	B	(111)(220)(200)			TiCO (0.1)	Granular	Al_2O_3 (3.3)	K:55%			0.20	0.16
	106	C	(220)(111)(200)			TiCO (0.1)	Granular	Al_2O_3 (1.5)	K:85%	TiN (0.2)	Granular	0.20	0.21
	107	C	(220)(200)(111)	TiN (1.8)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (0.8)	K:62%			0.24	0.20
	108	C	(111)(220)(200)					Al_2O_3 (2.6)	K:94%	TiN (0.5)	Granular	0.19	0.23
	109	D	(111)(220)(200)			TiCNO (0.1)	Granular	Al_2O_3 (5.2)	K:73%			0.15	0.17
	110	D	(220)(111)(200)	TiCN (1.4)	Granular			Al_2O_3 (8.1)	K:62%			0.15	0.22
	111	D	(111)(220)(200)					Al_2O_3 (2.8)	K:100%			0.16	0.19
	112	D	(111)(220)(200)	TiC (1.2)	Granular			Al_2O_3 (4.3)	K:73%	TiN (0.2)	Granular	0.16	0.17

TABLE 19 (a)

Type		Substrate Symbol	Hard Coating Layer															
			Innermost Layer		Inner Layer													
					First Devided Layer		First Dividing Layer		Second Divided Layer		Second Dividing Layer		Third Divided Layer		Third Dividing Layer		Forth Divided Layer	
			Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure
Coated Cemented Carbide Cutting Tools of the Invention	113	F	TiN (0.4)	Granular	TiCN (1.6)	Elongated Growth	TiN (0.2)	Granular	TiCN (1.5)	Elongated Growth							TiCN (2.3)	Elongated Growth
	114	F	TiN-TiCN (1.0)	Granular	TiCN (0.9)	Elongated Growth	TiN (0.1)	Granular	TiCN (1.0)	Elongated Growth								
	115	F			TiCN (1.9)	Elongated Growth	TiN (0.2)	Granular	TiCN (2.0)	Elongated Growth	TiN (0.3)	Granular	TiCN (1.9)	Elongated Growth				
	116	F			TiCN (2.2)	Elongated Growth	TiN (0.3)	Granular	TiCN (2.3)	Elongated Growth								
	117	G	TiC-TiN (0.9)	Granular	TiCN (1.1)	Elongated Growth	TiN (0.2)	Granular	TiCN (1.1)	Elongated Growth	TiN (0.1)	Granular	TiCN (1.0)	Elongated Growth				
	118	G			TiCN (3.4)	Elongated Growth	TiN (0.2)	Granular	TiCN (3.3)	Elongated Growth								
	119	G	TiN (0.5)	Granular	TiCN (1.1)	Elongated Growth	TiN (0.1)	Granular	TiCN (0.8)	Elongated Growth	TiN (0.2)	Granular	TiCN (1.0)	Elongated Growth				
	120	G			TiCN (1.7)	Elongated Growth	TiN (0.2)	Granular	TiCN (1.6)	Elongated Growth								
	121	G			TiCN (2.2)	Elongated Growth	TiN (0.2)	Granular	TiCN (2.0)	Elongated Growth								
	122	E	TiCN (0.6)	Granular	TiCN (0.7)	Elongated Growth	TiN (0.2)	Granular	TiCN (0.6)	Elongated Growth	TiN (0.2)	Granular	TiCN (0.6)	Elongated Growth	TiN (0.2)	Granular	TiCN (0.7)	Elongated Growth
	123	E	TiN (0.3)	Granular	TiCN (1.3)	Elongated Growth	TiN (0.1)	Granular	TiCN (1.3)	Elongated Growth								
	124	E	TiN (0.3)	Granular	TiCN (1.8)	Elongated Growth	TiN (0.1)	Granular	TiCN (1.7)	Elongated Growth								
	125	E'			TiCN (1.4)	Elongated Growth	TiN (0.3)	Granular	TiCN (1.3)	Elongated Growth								
	126	E'	TiC (0.7)	Granular	TiCN (1.5)	Elongated Growth	TiN (0.2)	Granular	TiCN (1.6)	Elongated Growth								

TABLE 19 (b)

Type		Sub-strate Symbol	Hard Coating Layer									Flank Wear (mm)	
			Inner Layer	First Intermediate Layer		Second Intermediate Layer		Outer Layer		Outermost Layer			
			Orientation	Compo-sition	Crystal Struc-ture	Compo-sition	Crystal Struc-ture	Compo-sition	Crystal Structure	Compo-sition	Crystal Struc-ture	Continuous Cutting	Interrupted Cutting
Coated Cemented Carbide Cutting Tools of the Invention	113	F	(220)(111)(200)	TiCN (1.4)	Granular	TiCO (0.1)	Granular	Al_2O_3 (0.2)	K:100%	TiN (0.2)	Granular	0.14	0.18
	114	F	(111)(220)(200)			TiCNO (0.2)	Granular	Al_2O_3 (0.7)	K:94%	TiN (0.2)	Granular	0.12	0.19
	115	F	(111)(220)(200)	TiCN (1.1)	Granular			Al_2O_3 (1.5)	K:100%			0.13	0.25
	116	F	(111)(200)(220)					Al_2O_3 (1.2)	K:94%	TiN (0.3)	Granular	0.14	0.21
	117	G	(111)(220)(200)			TiCO (0.1)	Granular	Al_2O_3 (0.5)	K:55%			0.12	0.20
	118	G	(220)(111)(200)			TiCO (0.1)	Granular	Al_2O_3 (2.0)	K:94%	TiN (0.4)	Granular	0.11	0.24
	119	G	(220)(200)(111)	TiN (1.7)	Granular			Al_2O_3 (0.8)	K:62%	TiN (0.5)	Granular	0.15	0.20
	120	G	(111)(220)(200)	TiC (2.9)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (1.2)	K:85%			0.14	0.19
	121	G	(220)(111)(200)					Al_2O_3 (1.0)	K:100%			0.12	0.23
	122	E	(111)(220)(200)					Al_2O_3 (0.8)	K:94%	TiN (0.3)	Granular	0.14 (Milling)	
	123	E	(220)(111)(200)	TiC (1.4)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (0.5)	K:100%			0.15 (Milling)	
	124	E	(111)(220)(200)			TiCNO (0.1)	Granular	Al_2O_3 (0.4)	K:100%	TiN (0.2)	Granular	0.14 (Milling)	
	125	E'	(220)(111)(200)	TiCN (0.8)	Granular			Al_2O_3 (0.3)	K:100%			0.15 (Milling)	
	126	E'	(111)(220)(200)			TiCNO (0.2)	Granular	Al_2O_3 (1.1)	K:94%	TiN (0.2)	Granular	0.14 (Milling)	

TABLE 20

Type		Substrate Symbol	Hard Coating Layer														Flank Wear (mm)	
			Innermost Layer		Inner Layer			First Intermediate Layer		Second Intermediate Layer		Outer Layer		Outermost Layer			
			Composition	Crystal Structure	Composition	Crystal Structure	Orientation	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure		
Coated Cemented Carbide Cutting Tools of Prior Art	99	A	TiN (1.0)	Granular	TiCN (9.5)	Granular	(111)(200)(220)			TiCNO (0.1)	Granular	Al_2O_3 (2.3)	α:100%	TiN (0.2)	Granular	0.57 (Chipping)	0.53 (Chipping)
	100	A			TiCN (6.1)	Granular	(220)(200)(111)	TiC (2.8)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (2.8)	α:100%	TiN (0.2)	Granular	0.61 (Chipping)	0.52 (Chipping)
	101	A	TiN (0.6)	Granular	TiCN (9.3)	Granular	(111)(200)(220)	TiC (2.0)	Granular			Al_2O_3 (1.9)	κ:40%	TiCN-TiN (0.6)	Granular	0.59 (Chipping)	0.43 (Chipping)
	102	A	TiN (0.5)	Granular	TiCN (6.0)	Granular	(200)(220)(111)	TiC (3.0)	Granular			Al_2O_3 (2.5)	α:100%	TiN (0.3)	Granular	0.60 (Chipping)	0.57 (Chipping)
	103	B			TiCN (8.4)	Granular	(111)(200)(220)			TiCO (0.1)	Granular	Al_2O_3 (3.4)	α:100%			0.64 (Chipping)	0.60 (Chipping)
	104	B	TiC-TiN (1.5)	Granular	TiCN (6.6)	Granular	(220)(200)(111)	TiC (3.6)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (2.1)	α:100%	TiN (0.3)	Granular	0.59 (Chipping)	0.39 (Chipping)
	105	B	TiN (1.7)	Granular	TiCN (8.7)	Granular	(200)(220)(111)			TiCO (0.1)	Granular	Al_2O_3 (3.2)	α:100%			Failure after 21.6 min. due to Layer Separation	Failure after 21.6 min. due to Layer Separation
	106	C			TiCN (9.8)	Granular	(111)(200)(220)			TiCO (0.1)	Granular	Al_2O_3 (1.6)	α:100%	TiN (0.2)	Granular	Failure after 19.5 min. due to Layer Separation	Failure after 20.8 min. due to Layer Separation
	107	C	TiC (0.4)	Granular	TiCN (2.5)	Granular	(220)(200)(111)	TiN (1.8)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (0.9)	κ:40%			Failure after 15.1 min. due to Layer Separation	Failure after 9.8 min. due to Layer Separation
	108	C	TiN (0.5)	Granular	TiCN (7.7)	Granular	(111)(200)(220)					Al_2O_3 (2.5)	α:100%	TiN (0.5)	Granular	Failure after 19.5 min. due to Layer Separation	Failure after 20.8 min. due to Layer Separation
	109	D	TiN (0.6)	Granular	TiCN (6.3)	Granular	(220)(200)(111)			TiCNO (0.1)	Granular	Al_2O_3 (5.0)	α:100%			0.59 (Chipping)	0.54 (Chipping)
	110	D	TiN (0.7)	Granular	TiCN (2.4)	Granular	(111)(200)(220)	TiCN (1.2)	Granular			Al_2O_3 (8.0)	α:100%			Failure after 13.9 min. due to Chipping	Failure after 3.6 min. due to Fracturing
	111	D	TiCN (0.5)	Granular	TiCN (8.2)	Granular	(220)(200)(111)					Al_2O_3 (2.9)	α:100%			Failure after 12.4 min. due to Chipping	Failure after 5.9 min. due to Fracturing
	112	D			TiCN (6.9)	Granular	(111)(200)(220)	TiC (1.3)	Granular			Al_2O_3 (4.2)	α:100%	TiN (0.3)	Granular	Failure after 11.5 min. due to Chipping	Failure after 6.5 min. due to Fracturing

TABLE 21

Type		Substrate Symbol	Hard Coating Layer: Innermost Layer		Inner Layer			First Intermediate Layer		Second Intermediate Layer		Outer Layer		Outermost Layer		Flank Wear (mm)	
			Composition	Crystal Structure	Composition	Crystal Structure	Orientation	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Composition	Crystal Structure	Continuous Cutting	Interruped cutting
Coated Cemented Carbide Cutting Tools of Prior Art	113	F	TiN (0.3)	Granular	TiCN (3.2)	Granular	(111)(200)(220)	TiCN (1.5)	Granular	TiCO (0.1)	Granular	Al_2O_3 (0.2)	α:100%	TiN (0.2)	Granular	Failure after 13.6 min. due to Chipping	Failure after 8.0 min. due to Fracturing
	114	F	TiN-TiCN (0.9)	Granular	TiCN (2.1)	Granular	(220)(200)(111)			TiCNO (0.2)	Granular	Al_2O_3 (0.7)	α:100%	TiN (0.2)	Granular	Failure after 16.0 min. due to Chipping	Failure after 7.6 min. due to Fracturing
	115	F			TiCN (6.5)	Granular	(111)(200)(220)	TiCN (1.2)	Granular			Al_2O_3 (1.5)	κ:40%			Failure after 14.4 min. due to Layer Separation	Failure after 3.1 min. due to Fracturing
	116	F			TiCN (4.6)	Granular	(200)(220)(111)					Al_2O_3 (1.2)	α:100%	TiN (0.3)	Granular	Failure after 15.1 min. due to Layer Separation	Failure after 6.3 min. due to Fracturing
	117	G	TiC-TiN (1.0)	Granular	TiCN (3.5)	Granular	(111)(200)(220)			TiCO (0.1)	Granular	Al_2O_3 (0.5)	α:100%			Failure after 17.4 min. due to Chipping	Failure after 5.8 min. due to Fracturing
	118	G			TiCN (7.0)	Granular	(220)(200)(111)			TiCO (0.1)	Granular	Al_2O_3 (2.0)	α:100%	TiN (0.4)	Granular	Failure after 16.2 min. due to Layer Separation	Failure after 4.5 min. due to Fracturing
	119	G	TiN (0.6)	Granular	TiCN (3.1)	Granular	(200)(220)(111)	TiN (1.8)	Granular			Al_2O_3 (0.8)	κ:40%	TiN (0.5)	Granular	Failure after 12.5 min. due to Chipping	Failure after 7.4 min. due to Fracturing
	120	G			TiCN (3.3)	Granular	(111)(200)(220)	TiC (2.8)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (1.2)	α:100%			Failure after 13.3 min. due to Layer Separation	Failure after 7.9 min. due to Fracturing
	121	G			TiCN (4.5)	Granular	(220)(200)(111)					Al_2O_3 (1.0)	κ:40%			Failure after 17.6 min. due to Layer Separation	Failure after 5.2 min. due to Fracturing
	122	E	TiCN (0.5)	Granular	TiCN (3.2)	Granular	(111)(200)(220)					Al_2O_3 (0.8)	α:100%	TiN (0.3)	Granular	0.41 (Chipping) (Milling)	
	123	E	TiN (0.3)	Granular	TiCN (2.6)	Granular	(220)(200)(111)	TiC (1.5)	Granular	TiCNO (0.1)	Granular	Al_2O_3 (0.5)	α:100%			0.37 (Chipping) (Milling)	
	124	E	TiN (0.3)	Granular	TiCN (3.5)	Granular	(111)(200)(220)			TiCNO (0.1)	Granular	Al_2O_3 (0.4)	α:100%	TiN (0.2)	Granular	0.33 (Chipping) (Milling)	
	125	E'			TiCN (3.0)	Granular	(220)(200)(111)	TiCN (0.9)	Granular			Al_2O_3 (0.3)	α:100%			0.38 (Chipping) (Milling)	
	126	E'	TiC (0.8)	Granular	TiCN (2.9)	Granular	(111)(200)(220)			TiCNO (0.2)	Granular	Al_2O_3 (1.1)	α:100%	TiN (0.2)	Granular	0.36 (Chipping) (Milling)	

Claims

1. A coated hard alloy blade member comprising a substrate formed of a hard alloy selected from the group consisting of a WC-based cemented carbide and a TiCN-based cermet, and a hard coating deposited on said substrate, characterized in that said hard coating includes an inner layer of TiCN having unilaterally grown crystals of an elongated shape and an outer layer of Al_2O_3 having a crystal form κ or $\kappa + \alpha$ wherein $\kappa > \alpha$.

2. A coated hard alloy blade member according to claim 1, wherein the TiCN in said elongated crystals of said inner layer has X-ray diffraction peaks such that strength at (200) plane is weak compared to strengths at (111) and (220) planes.

3. A coated hard alloy blade member according to claim 1 or claim 2, wherein said hard coating further includes an innermost layer of one or more of granular TiN, TiC, or TiCN formed underneath said inner layer.

4. A coated hard alloy blade member according to any one of the preceding claims, wherein said hard coating further includes an outermost layer of one or both of granular TiN or TiCN formed on said outer layer of Al_2O_3.

5. A coated hard alloy blade member according to any one of the preceding claims, wherein said hard coating further includes a first intermediate layer of one or more of granular TiC, TiN, or TiCN formed between said inner layer of TiCN and said outer layer of Al_2O_3.

6. A coated hard alloy blade member according to any one of the preceding claims, wherein said hard coating further includes a second intermediate layer of one or both of TiCO or TiCNO formed between said inner layer of TiCN and said outer layer of Al_2O_3.

7. A coated hard alloy blade member according to any one of the preceding claims, wherein said inner layer of TiCN further includes one or more layers of TiN such that the inner layer is divided by the layers of TiN.

8. A coated hard alloy blade member according to any one of the preceding claims, wherein said WC-based cemented carbide consists essentially of 4 - 12 % by weight of Co, 0 - 7 % by weight of Ti, 0 - 7 % by weight of Ta, 0 - 4 % by weight of Nb, 0 - 2 % by weight of Cr, 0 - 1 % by weight of N, and balance W and C.

9. A coated hard alloy blade member according to claim 8, wherein the maximum amount of Co in a surface layer of the substrate ranging up to 100 µm depth from a surface thereof is 1.5 to 5 times as much as the amount of Co in an interior 1 mm deep from the surface.

10. A coated hard alloy blade member according to any one of the preceding claims, wherein said TiCN-based cermet consists essentially of 2 - 14 % by weight of Co, 2 - 12 % by weight of Ni, 2 - 20 % by weight of Ta, 0.1 - 10 % by weight of Nb, 5 - 30 % by weight of W, 5 - 20 % by weight of Mo, 2 - 8 % by weight of N, optionally no greater than 5 % by weight of at least one of Cr, V, Zr or Hf, and balance Ti and C.

11. A coated hard alloy blade member according to claim 10, wherein hardness in a surface layer of the substrate ranging up to 100 µm depth from a surface thereof is more than 5% harder than hardness of an interior 1 mm deep from the surface.

12. The use of a hard coated blade member according to any one of the preceding claims in cutting tools.

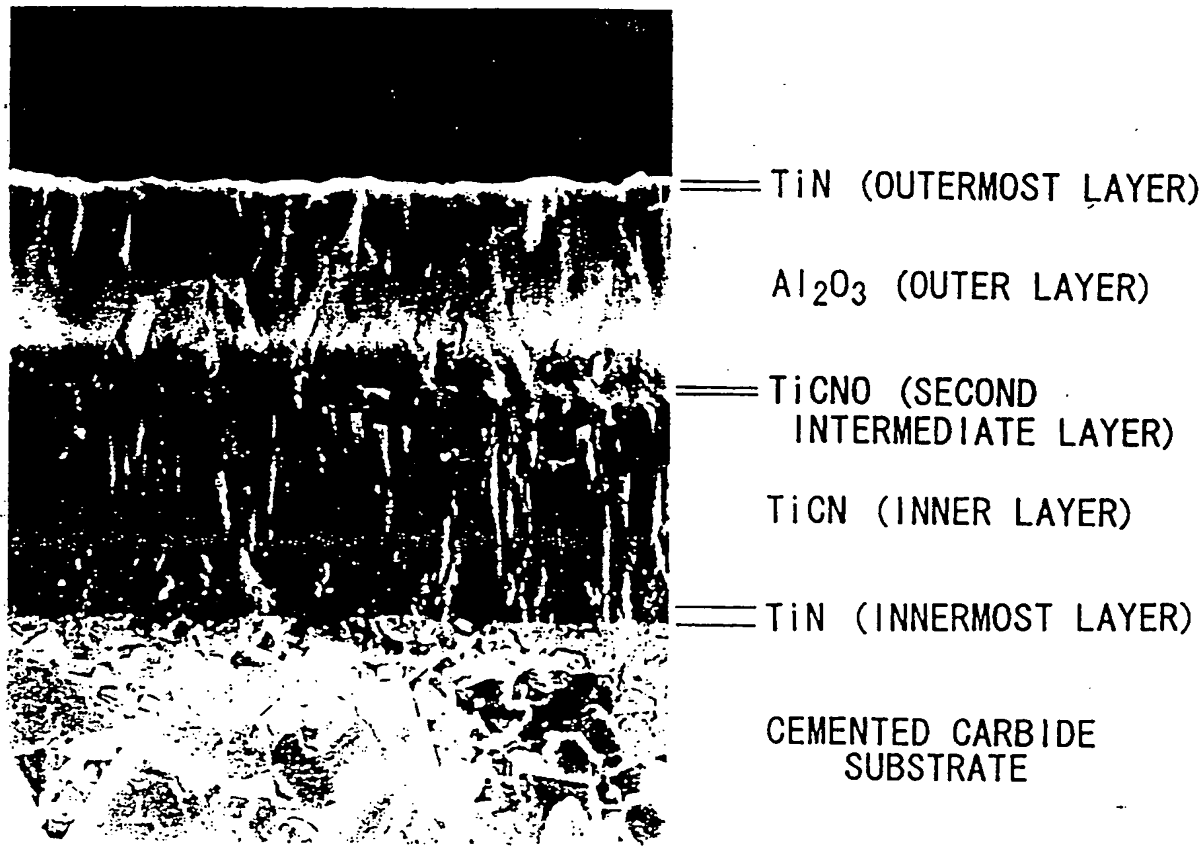

FIG. 1 COATED CEMENTED CARBIDE CUTTING TOOL "64"

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 95 10 3339

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
Y	PATENT ABSTRACTS OF JAPAN vol. 012, no. 479 (C-552), 14 December 1988 & JP-A-63 195268 (MITSUBISHI METAL CORP), 12 August 1988, * abstract *	1,3,12	C23C30/00 C23C16/40 C23C16/36
Y	PATENT ABSTRACTS OF JAPAN vol. 018, no. 392 (C-1228), 22 July 1994 & JP-A-06 108254 (MITSUBISHI MATERIALS CORP), 19 April 1994, * abstract *	1,3,12	
A	EP-A-0 594 875 (MITSUBISHI MATERIALS CORP) 4 May 1994 * claims 1,2; table 1 *	1-12	
A	EP-A-0 408 535 (SECO TOOLS AB) 16 January 1991		
P,X	DATABASE WPI Section Ch, Week 9432 Derwent Publications Ltd., London, GB; Class L02, AN 94-259893 XP002007194 & JP-A-06 190 605 (MITSUBISHI MATERIALS CORP) , 12 July 1994 * abstract *	1,12	TECHNICAL FIELDS SEARCHED (Int.Cl.6) C23C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	1 July 1996	Patterson, A

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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